ANNUAL REPORT 12

Centre of Excellence Activities and Centre for Climate Dynamics

Bjerknes Centre
for Climate Research

TEN YEARS OF EXCELLENCE

NERSC
Nansen Center, Bergen
uni Research

Established by the Research Council of Norway
Norwegian Centre of Excellence

Statement from the Board of Directors:

«The board is very satisfied with the results of the Bjerknes Centre in 2012. The centre organised a successful 10-year anniversary conference on climate change in high latitudes, which documented the high level of its own research and brought top scientists from many countries to share their results with the local community. The high quality of outreach that has been developed through the ten years as CoE, was documented nicely in the open public seminar on November 30, marking the final day of the CoE. Publication output was very high, and reached record levels. The board is pleased to see that publication output has been going up steadily through the centre's lifetime, and has risen at a higher rate than the number of scientists of the centre, thus indicating increased scientific productivity. The board is also satisfied that the synthesis activities that have formed the backbone of activities in 2011–12 have led to a number of publications with potentially high impact, thus providing a legacy of results for the future. The CoE period has now come to a successful end, and the board is pleased to note that all four partner institutions continue in the Bjerknes Centre under the new agreement, and that the centre continues to receive long-term core funding from the Ministry of Higher Education and Research. This support is an acknowledgement of the status the centre has obtained nationally and internationally through the successful execution of its 10-year term as a CoE.»

PHOTO: ANNE E. BJUNE

10 YEARS AS A CENTRE OF EXCELLENCE

Eystein Jansen, Director at the Bjerknes Centre for Climate Research. PHOTO: EIVIND SENNESET

2012 was the last year with funding under the Norwegian Centre of Excellence (CoE) programme. It therefore marks the end of one period and the start of another. Not surprisingly we used the year to dwell on what we have achieved and also to define the future course of the centre. During our ten years as a CoE, the Bjerknes Centre has achieved high visibility for high-quality science on the climate system, both nationally and internationally. We have built a climate research centre that receives excellent scores in international evaluations of Norwegian science quality. We publish in the most prestigious journals, and our work is cited twice as often as the international (and national) norm. We recruit highly talented researchers from the international community. The growth in scientific output and personnel is testified in the statistics we present for the 10-year period in this report.

Several important aspects characterise what we achieved in 2012. We published 120 papers in peer-review journals, the highest number ever, testifying to a steady growth of scientific results from the centre. Our synthesis projects were active and a number of scientific outcomes are already submitted to the peer-review journals, and a number of results are being written up as this report is being prepared. We finished a series of papers within the deadline set by the IPCC-WG1 for papers that can be cited in the 5th Assessment report, which is due late September 2013. Several papers were submitted presenting results from the Norwegian Earth System Model (NorESM). The model results are being used globally, and at the time of writing more than 160 papers using the NorESM are registered. A number of papers compare the models using various metrics and overall it appears that NorESM is doing very well on a number of critical metrics of performance. The first results of the low-resolution version for long-term, mainly paleoclimate, studies have been submitted to high-profile journals (and accepted and published early in 2013). Hence the model system is fulfilling our ambitions of having a state-of-the-art earth system model.

To celebrate our 10-year anniversary, we organised the Conference on High Latitude Climate Change in September, with more than 250 attendees and a large number of oral and poster presentations. It was very pleasing to see the quality of the BCCR contributions at the conference. They were clearly on the same quality level as the invited contributions from leading scientists in the field. A number of the contributions came from our younger scientists indicating that the recruitment in the centre is working well.

As the 10 years as a CoE drew to its close, we held a public seminar presenting our main findings to the public. The seminar was well attended and we received lots of praise from those who were present for our capability to communicate complex science to a non-scientific audience. I believe this is one of our strengths that we have developed through a strong emphasis on outreach and communication during the first decade of Bjerknes Centre activities.

The partner institutions of the Bjerknes Centre agreed in 2012 on a new long-term commitment to the Bjerknes Centre, and the governance structure of the new, second phase of the centre was agreed upon. The Bjerknes Centre thus will continue as the flagship and co-ordination vehicle for natural science based climate research in Bergen, joining groups from the University of Bergen, Uni Research, the Institute for Marine Research and the Nansen Center. The University will continue to host the centre, and the funding from the Government to the Centre for Climate Dynamics at the Bjerknes Centre will form the core of the activities which will be extended by other projects as well as integration in various thematic groups. We have therefore laid the foundation both in terms of science and in terms of organisation for a solid future for the Bjerknes Centre.

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PHOTO: BJØRN KVISVIK

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A CENTRE FOR **EXCELLENT RESEARCH** ON THE TOP OF EUROPE

The Bjerknes Centre is the largest climate research centre in the Nordic countries with a focus on the natural science aspects of climate change.

After 10 years as a centre under the Research Council of Norway's centres of excellence schemes, finishing up at the end of 2012, the centre has received a long-term core funding from the Government. This funding is organised in the Centre for Climate Dynamics at the Bjerknes Centre. Our ambition is to continue to be a leading international centre for climate research, focusing on northern Europe and the Polar regions within a global context. Regional climate modeling in regions both in high and low latitudes have been added to the scope of the centre.

The centre has an international profile with leading expertise within climate understanding, climate modelling and scenarios for future climate changes, and quantification of climate changes. In order to carry out the centre's ambitions, research activities are organized into five interdisciplinary research groups that provide knowledge of the following main research themes:

- Past, present and future climate changes and distinguishing natural and man-made changes.
- Abrupt and regional climate changes in the context of the global climate system.
- The role of the oceans in the climate system, ocean–sea ice–atmosphere processes, feedback mechanisms caused by the carbon cycle and other processes.

Research groups

The Research Groups are focused teams including scientists, students and technical staff that combine observations with numerical modelling.

1. **PAST CLIMATE VARIABILITY**
   Understanding long-term natural climate variability of the past is essential for understanding present and future climate changes.

2. **PRESENT-DAY CLIMATE CHANGES**
   The North Atlantic ocean circulation and storm tracks heat up the North, but also make it a challenge to assess the natural modes of variability in the region.

3. **OCEAN, SEA ICE AND ATMOSPHERE PROCESSES**
   Exchanges between ocean, sea ice and atmosphere are crucial to the climate system, and simulations of the future climate depend on their proper representation.

4. **BIOGEOCHEMICAL CYCLES**
   Biogeochemical processes are important in the global climate system and affect how much of man-made CO_2 emissions is taken up by the ocean and land surfaces.

5. **FUTURE CLIMATE AND REGIONAL EFFECTS**
   Global climate changes have local effects and might influence extreme weather and marine ecosystems in Norway and the Arctic, as well as having effects on water resources and health in lesser-developed countries.

More about our research groups at www.bjerknes.uib.no/research/

Established by the Research Council of Norway

Norwegian Centre of Excellence

SFF Norwegian Centre of Excellence

The Bjerknes Centre is a Norwegian Centre of Excellence (CoE) in climate research, and is coordinated by the University of Bergen in cooperation with Uni Research, Nansen Environmental and Remote Sensing Center, and the Institute of Marine Research.

SYNTHESISING OUR RESEARCH

In order to secure the outcome and legacy of our ten years as a centre of excellence, we have in 2011 and 2012 used much of our resources to support a series of synthesis projects. The goal has been to produce scientific syntheses in the form of papers in key areas where we have had much activity. A selection of the synthesis results are presented in the following section.

A BRIEF HISTORY OF CLIMATE

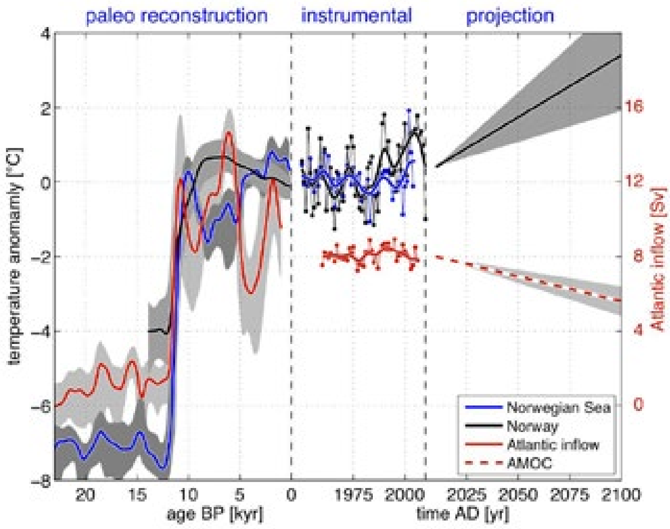
It is now timely for the first time to present a holistic and comprehensive description of the variable Norwegian marine climate from the Last Glacial Maximum to the end of the 21st century.

Tor Eldevik

The Gulf Stream's northern limb extends through the Norwegian Sea to the cold Arctic, a region that appears to be particularly sensitive to climate change. The relatively warm Atlantic inflow to the Norwegian Sea progressively gives up its excess heat en route toward the Arctic, and thus moderates the regional climate. This interaction between variable ocean circulation and climate is therefore central to the current understanding of past, present, and projected future climate change in the northern seas region.

In the conclusion of the Bjerknes Centre's CoE period, it is now timely for the first time to present a holistic and comprehensive description of the variable Norwegian marine climate from the Last Glacial Maximum to the end of the 21st century. We have thus compiled and combined: 1) available paleo reconstructions, 2) observations from the instrumental


PHOTO: JOSTEIN BAKKE



A brief history of climate from the Last Glacial Maximum to global warming. The evolution of Norwegian Sea (blue) and land (black) temperatures are overlaid by the estimated strength of the Atlantic inflow to the Norwegian Sea (red). In the case of future climate, change relates to the projected large-scale Atlantic Meridionial Overturning Circulation (AMOC). Grey shades indicate the spread in paleo data and future projections; individual data points are the annual values of the instrumental record. Note that there is a factor 1:200 between present/future and paleo time scales. The climate model AMOC projections include the full range of "Representative Concentration Pathways" (IPCC AR5), and temperature covers the projected range between an approximate doubling and quadrupling of atmospheric CO2 content by the end of the century (IPCC AR4).

record, and 3) future projections from climate models. The figure broadly documents how both land and ocean remained very cold (but still variable) through to the Younger Dryas about 12,000 years ago, which was followed by a relatively abrupt transition into the temperate climate of the Holocene. The instrumental record describes a modern climate of more constant temperatures, but nevertheless with a pronounced warming trend consistent with global warming, particularly over land. The trend is projected to persist through the 21st century, with a three-degree warming by 2100.

Roughly speaking, the strength of the Atlantic inflow reflects and thus may explain reconstructed temperatures. It is estimated to be relatively marginal during the cold millennia, and then to shift to a mean level like the present to accommodate Holocene climate. The projected future is qualitatively different. Under global warming, the differential planetary heating by solar radiation is slightly offset, and the compensating poleward heat transport of the Atlantic Ocean is consistently reduced. One may speculate that the (slightly) weaker inflow with the most recent ocean and land warming is evidence of a present climate that has already become qualitatively like the projected.

REFERENCE

T. Eldevik (UiB/BCCR), B. Risebrobakken (Uni/BCCR), A. Bjune (Uni/BCCR), et al., 2013:
A brief history of climate – the northern seas from Last Glacial Maximum to global warming.
To be submitted to Quat. Sci. Rev.

THE ROLE OF THE BARENTS SEA IN **THE ARCTIC CLIMATE SYSTEM**

Present global warming is amplified in the Arctic and accompanied by unprecedented sea-ice decline.

Lars Henrik Smedsrud

Located along the main pathway of Atlantic Water entering the Arctic, the Barents Sea is the site of coupled feedback processes that are important for creating variability in the entire arctic atmosphere-ice-ocean system.

As warm Atlantic water flows through the Barents Sea, it loses heat to the Arctic atmosphere. Warm periods, like today, are associated with high northward heat transport, reduced artic sea-ice cover, and high surface air temperatures. The cooling of the Atlantic inflow creates dense water that sinks to great depths in the arctic basins, and ~60 % of the Arctic Ocean carbon uptake is removed from the carbon-saturated surface this way.

Recently, anomalously large ocean heat transport has reduced sea-ice formation in the Barents Sea during winter. The missing Barents Sea winter ice makes up a large part of observed winter arctic sea-ice loss, and in 2050 the Barents Sea is projected to be largely ice free throughout the year, with a 4°C summer warming in the formerly ice-covered areas.

The heating of the Barents atmosphere plays an important role both in "arctic amplification" and the arctic heat budget. The heating also perturbs the large-scale circulation through expansion of the Siberian High northwards, with a possible link to recent continental wintertime cooling. Large atmosphere-ice-ocean variability is evident in proxy records of past climate conditions, suggesting that the Barents Sea has had an important role in Northern Hemisphere climate for at least the last 2500 years.

REFERENCE

Lars H. Smedsrud, Igor N. Esau, Randi B. Ingvaldsen, Tor Eldevik, Peter M. Haugan, Camille Li, Vidar Lien, Are Olsen, Abdir Omar, Odd H. Otterå, Bjørg Risebrobakken, Anne B. Sandø, Vladimir Semenov and Svetlana A. Sorokina. (In revision) Reviews of Geophysics, 2013.

DECADAL VARIATIONS IN THE GYRE CIRCULATION

Scientists from the Bjerknes Centre show in a recently published article (Langehaug et al. 2012, Journal of Climate) that a combination of three different factors contributes significantly to the decadal variations in the horizontal oceanic circulation (gyre circulation) south of Greenland and Iceland: cold water masses from the Nordic Seas and Labrador Sea, and the wind over the subpolar region.

This model study therefore gives an increased understanding of which factors that can cause changes in the strength of the gyre circulation. This is important to understand, because this circulation is essential in the distribution of heat and salt in our ocean region.

REFERENCE

Langehaug, H. R., I. Medhaug, T. Eldevik, and O. H. Otterå (2012), Arctic/Atlantic exchanges via the Subpolar Gyre, Journal of Climate, doi:10.1175/JCLI-D-11-00085.1.

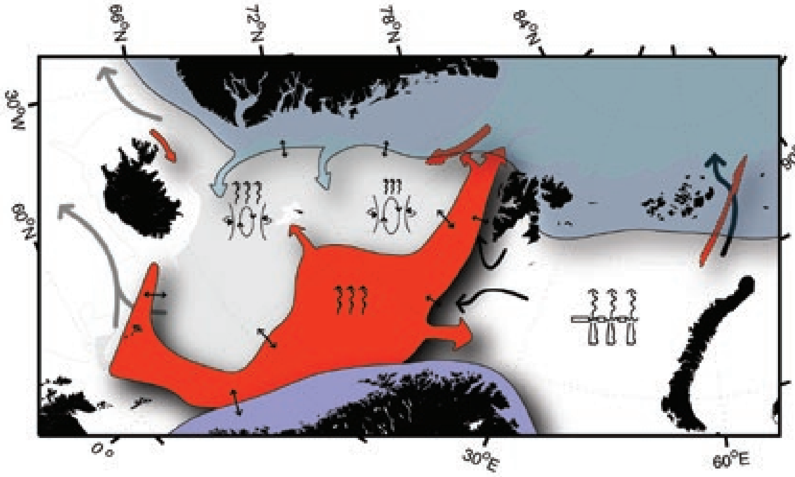
VENTILATION, PATHWAYS, AND OVERFLOWS OF THE NORDIC SEAS

The Atlantic Meridional Overturning Circulation (AMOC) brings warm and saline waters to the arctic regions where they affect marine climate and exchanges, bringing for example absorbed greenhouse gases away from the surface.

J. Even Ø. Nilsen

The overflows from the Nordic Seas contribute two-thirds of the AMOC. These overflows result from ventilation of the Atlantic Water entering the Nordic and the Arctic, of which two-thirds is transformed and returns as Overflow Water (OW) feeding the deep branch of the AMOC.

In this work we address the transformation by reviewing and quantifying the relative contributions from the different processes that modify and densify surface waters, and contribute to the ventilation of the "Arctic Mediterranean". The processes in focus are: Mixing between the Atlantic and Arctic Waters; Freshwater import from the coastal currents; Convection and heat loss within the Atlantic Water in the Norwegian Sea, as well as convection in the Greenland and Iceland Seas producing intermediate and deep waters; and Cooling and ice formation, especially over the shelves of the Barents Sea, producing brine-enriched cold water that cascades into the deeper ocean. Assessing the relative contributions from these processes is of key importance for understanding the northernmost limb of the AMOC.



Conceptual image of the different dense water formation processes in the area. The coloured surfaces outline approximate water mass extension and flow of (from top) Polar Water (blue), Atlantic Water (red), and Norwegian Coastal Water (purple). The small drawings symbolise the different processes discussed in the paper: Cross-frontal mixing (double arrows); atmospheric cooling (wavy arrows); overturning gyres (loops); ice formation and brine release in the Barents Sea (in the east). Thick black arrows show sinking shelf-produced water to the basins, and grey arrows in the Atlantic overflows from the Nordic Seas.

This review confirms and quantifies that the relative contributions to the overflows from the source processes and regions are not dominated by deep convection in the central seas. In terms of producing waters of OW density, the transformation of Atlantic Water in the Nordic Seas gives by far the most voluminous contribution, with ~4 Sv (1 Sv=10^6 m^3 s^{-1}), whereas the Greenland Sea Gyre likely contributes less than 1 Sv. The dense waters produced by ice formation in the Barents Sea and the transformation and convection in the Iceland Sea, both may contribute with as much as ~2 Sv each. Furthermore, a thorough review of pathways and traced contributions to the actual overflows, strengthen these relations where Atlantic-derived waters and deep water from the Arctic and Nordic Seas in general contribute far more than the Greenland Sea produced intermediate waters.

REFERENCE

Nilsen, J. E. Ø. (NERSC/BCCR), T. Eldevik (UiB/BCCR), Ø. Skagseth (IMR/BCCR) et al., 2013: Ventilation, Pathways, and Overflows of the Nordic Seas. To be submitted to Prog. Oceanogr.

GYRE CIRCULATION – LONG TERM VARIABILITY

The subpolar gyre of the North Atlantic is the key region for the formation of water masses that enter the Nordic Seas and feed into the global Meridional Overturning Circulation (MOC).

Trond Dokken

The instrumental time series of the ocean interior cover at most the last 50 years. Questions regarding, if and how, multidecadal variability are operating on longer time scales can therefore not be resolved from instrumental analyses alone. Therefore, in this synthesis, Bjerknes researchers use novel paleo- data constraints on key ocean–atmospheric variables, data syntheses and data–model comparisons to elucidate the origin and dynamics of observed variability related to long-term gyre circulation changes.

By reconstructing key oceanographic variables from the inflow areas to the Nordic Seas, a strong coupling to the longest instrumental oceanographic and atmospheric records has been demonstrated, shedding new insight on the decadal scale variability of the system for the last 500 years. An overall objective for the project has been to better resolve the atmospheric processes that govern observed changes in the gyre configuration, and how the ocean and atmosphere may share information on multi-decadal and longer time scales.

A large component of the gyre circulation is wind-driven, and it is generally accepted that the North Atlantic Oscillation (NAO) is a key atmospheric part of it. Equally, it is documented that the inflow to the Nordic Seas is also related to the zonal airflow (the westerlies), again closely associated to the NAO.

In addition to the direct wind-driven system associated to the NAO, there is also a longer-frequency variability occurring in the North Atlantic – the so-called Atlantic Multidecadal Oscillation (AMO), commonly associated with the overturning circulation. The research has demonstrated a robust link from interannual to multidedacal time scales between the ocean and the atmospheric circulation in winter. The atmospheric anomalies associated with these AMO-related changes are however perpendicular (meridional) to the anomalies associated with the NAO (zonal). How these two principal wind anomalies combine and integrate over the Nordic Seas remains to be better understood.

The project has also studied how long reconstructed data series over the past 500 years compared to long modelling simulation. The variability of the simulated North Atlantic gyre circulation is diagnosed from an Empirical Orthogonal Function (EOF) analysis of the barotropic streamfunction of the vertically-integrated transport. The leading mode is the intergyre gyre component (IGG) between the subpolar gyre and subtropical gyre, and explains a large part of the variance. This mode is characterized by an anomalous wind-driven circulation straddling the boundary between the gyres, and typically reflects north–south variations in the extension of the sub-tropical gyre. Furthermore, the IGG variability is closely linked with the simulated NAO index. The simulated IGG index shows a remarkable fit to the reconstructed water-mass record on decadal time scales. The model–data comparison thus tentatively suggests that positive phases of the IGG (and thus a more northward extended subtropical gyre) is associated with water masses of more subtropical origin entering the Nordic Seas.

UNDERSTANDING ATLANTIC AND PACIFIC **JET STREAM FLUCTUATIONS**

Atmospheric jet streams are fast-flowing currents of air found approximately 10 km above sea level in the extratropical regions of both hemispheres. Because these jets influence regional weather patterns, there is great interest in understanding the factors that control their path, strength and variations.

A study by researchers at the Bjerknes Centre for Climate Research offers a clearer understanding of the real-world jets in terms of the jet-driving processes established from theory.

Eddy driving, which creates north-south shifts in the jet, is found to be important for both the Atlantic and Pacific jets; thermal driving, which creates changes in jet strength, is found to be equally important for the Pacific jet.

The results of this study provide an intuitive dynamical description of atmospheric variability in terms of actual fluctuations of the jets. In addition, they have the potential to help evaluate how the jets will respond to climate changes such as global warming.

REFERENCE

Thermally driven and eddy-driven jet variability in reanalysis
Camille Li and Justin J. Wettstein, (2012) Journal of Climate, Vol. 25, No. 5, pp. 1587-1596 http://dx.doi.org/10.1175/JCLI-D-11-00145.1.

CONTRIBUTING TO **THE IPCC REPORT**

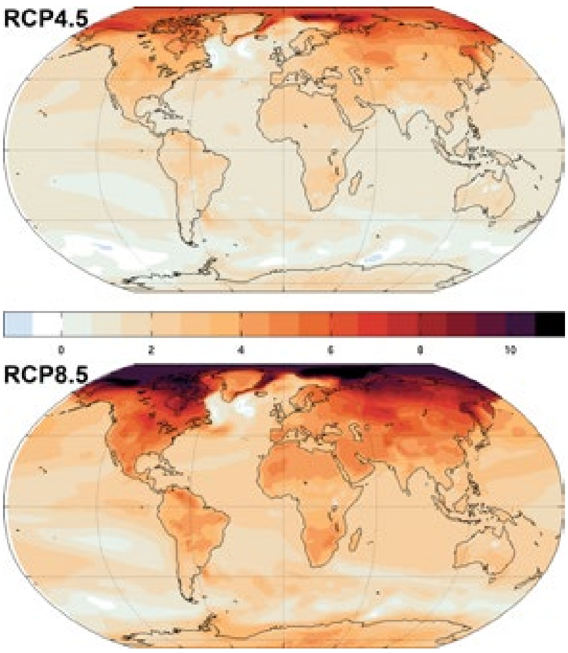
Helge Drange

NorESM, the Norwegian Earth System Model, is the Norwegian contribution to the suite of global climate models that form the modeling basis for, among other projects and programs, the United Nations' Intergovernmental Panel on Climate Change (IPCC). NorESM is a nationally coordinated effort, funded by the Research Council of Norway, with eight participating institutions headed by the Bjerknes Centre.

NorESM is based on the climate community model from the National Center for Atmospheric Research (NCAR) in Boulder, USA. Unique to NorESM are chemistry–aerosol–cloud–radiation interactions in the atmospheric module developed in Oslo, an isopycnic coordinate ocean model developed in Bergen, and an ocean carbon cycle model originally developed in Hamburg, Germany, and implemented into the NorESM framework.

Through 2011–2012, a series of NorESM-simulations have been run on the high-performance computers in Norway. These simulations include long (500-year) control experiments with constant incoming solar flux, fixed composition of the atmospheric greenhouse gases (GHGs), and fixed emissions of aerosols; hind-cast experiments for the period 1850–2005 with observed and reconstructed variations caused by solar variability, volcanic eruptions and human-induced GHG concentrations and aerosol emissions; and four sets of climate-scenario integrations for the present century. In addition to this, similar experiments have been carried out with prescribed CO_2 emissions instead of atmospheric concentrations. In these latter experiments, a fully interactive carbon cycle is enabled in NorESM.

Figure X shows the simulated change in global, annual mean temperature between the time periods 2071–2100 and 1976–2005 for two widely different emission scenarios. The upper panel shows a scenario with modest (fairly low) emissions of GHGs in the 21st century, whereas the lower panel shows a "business-as-usual" scenario. For the given time periods, the two projections lead to an annual mean global warming of 1.9 and 3.1 °C, respectively. The warming is most pronounced in the high northern latitudes. This is partly caused by the uneven distribution of land between the two hemispheres, and particularly polar amplification feedbacks in the Arctic.



Extensive model description and results are published as a Special Issue of the open access journal Geoscientific Model Development. So far, more than 100 submitted, in review or accepted publications have used output from NorESM.

WIND AND SEA SURFACE HEIGHT REVEAL CHANGES IN WARM WATER INFLOW

The authors of a study presented in Journal of Geophysical Research, Richter et al., found that the sea-surface height in the Nordic Seas plays a crucial role in driving the inflow from the North Atlantic Ocean.

It is shown that the variability of the Faroe Current responds primarily to an oceanic regime dominated by steric height changes in the interior Nordic Seas – that is, slow variations primarily driven by changes in the ocean temperatures. In contrast, variations in the Norwegian Atlantic Slope Current measured at the Svinøy section are largely driven by the much more rapid wind forcing that piles water onto shallower waters and causes strong cross-slope sea-surface height gradients along the European shelf.

It is found that the variability of the two sea-surface height modes can be captured by land-based tide gauges, and the gauges therefore can be used to reconstruct inflow anomalies back in time.

The results indicate that periods with high inflow anomalies coincide with warm anomalies passing through the system and vice versa. Since volume transports toward the Nordic Seas are important with respect to the heat and freshwater budgets of the region, the reconstructed time series provide valuable insights into past climatic states of the region.

REFERENCE

Richter, K., O. H. A. Segtnan, and T. Furevik (2012), Variability of the Atlantic inflow to the Nordic Seas and its causes inferred from observations of sea surface height, J. Geophys. Res., 117, C04004, doi:10.1029/2011JC007719.

HOLOCENE CLIMATE VARIABILITY
IN THE NORTH ATLANTIC REGION

The study of past climates offer an opportunity to examine the working of the earth system under a much wider range of forcing than those experienced during the historical period.

Jostein Bakke

During ten years with centre of excellence status at the Bjerknes Centre for Climate Research, many projects and scientists have been involved in reconstructions using various methods to resolve past climate variability covering the Holocene time period (11 700 yrs. BP – present). Detailed reconstructions of Holocene climate focusing on the rate of change, type of variability and rapid events provide important information about fundamental mechanisms in the climate system.

The study of past climates offer an opportunity to examine the workings of the earth system under a much wider range of forcing than those experienced during the historical period.

The time period called the Holocene can broadly be divided into three phases. The first phase, the Preboreal, lasting from about 11,700 to about 9000 years before present (BP). The second covers the period from about 9000 to about 6000 years BP and is called the ''Holocene Thermal Maximum'' (HTM), referring to warm conditions in northern mid- to high latitudes. The third phase is called the ''Neoglacial'', which is a period of glacier expansion all over the Northern Hemisphere.

In our analyses we have focused on the last 6000 years, as this time span is of particular interest to the understanding of the Earth system because the boundary conditions of the climate system did not change dramatically, and because abundant, detailed regional palaeoclimatic proxy records cover this period.

We have collected altogether 14 state-of-the-art glacier reconstructions based on multi-proxy analyses of sediments deposited in distal glacier-fed lakes covering the entire Scandinavia. Few approaches in palaeoscience have the potential to portray the spatial, temporal, and scalar expression of climate variability more accurately than the history of alpine glaciers worldwide. They are an underused resource in solving the puzzle of the Holocene drivers of global climate.

In order to be able to compare the individual records, we have used the same principal components analysis (PCA) approach on all records in order to isolate the glacial component of the sediments. Further, we have compared the glacial records with altogether 32 individual pollen based reconstructions of July temperature. This data coverage is exclusive for Norway and gives a detailed picture of regional temperature changes over Scandinavia throughout the Holocene. Finally, we used 11 sea-surface temperature series reconstructed with various methods to portray the spatial temperature variability over the North Atlantic Ocean through time. The resulting analyses pinpoint the role of orbital forcing in the Northern Hemisphere cooling, the effect of large-scale atmospheric circulation changes at 4k BP and 2.7k BP and the effect of changes in the ocean heat transport during the "Little Ice Age" at high northern latitudes.

PHOTO: JOSTEIN BAKKE

THE CHANGING CARBON FLUX OF THE NORTH ATLANTIC AND ARCTIC OCEAN

Emil Jeansson

PHOTO: JOSTEIN BAKKE

The relative CO_2 uptake of the North Atlantic and the Arctic Ocean, and the dominant fluxes to these regions are evaluated; how may these change over this century?

The North Atlantic contains the largest inventory of anthropogenic carbon, per unit area (e.g., Sabine et al., 2004), and it is vital to know the efficiency of this sink in the future. Recent findings have shown a reduced uptake connected to a weakened meridional overturning circulation (Pérez et al., 2013), and observational time-series have shown that the Norwegian Sea is a decreasing carbon sink (Skjelvan et al., 2008). In addition, the large changes in seasonal sea-ice extent in the Arctic Ocean may have large implications for the future carbon sink. Due to the strong connection between the North Atlantic and the Arctic Ocean, these regions should be studied together, because changes in one region can transfer rapidly to the other.

For the analysis we employed one global (BCM-C) and one regional (SINMOD) model, used to simulate the North Atlantic (0 to 70°N), and the Arctic Ocean (70 and 90°N), respectively. Two analyses were undertaken: a century-scale analysis of annual regional air-sea fluxes to enable comparison of the extent and relative variability of CO_2 fluxes, and a time-lapse comparison of the inter-regional variability of CO_2 fluxes with associated variability in hydrography and the carbonate system. For the latter the means of the time slices were chosen as 2026-2035 and 2090-2099, which represents short term changes relevant to medium term climate policy and end of the century simulations representing long-term sensitivity of the coupled regions.

The paper identifies the changing ocean carbon sink and furnishes information for key hotspots where observing systems should be located.

The study evaluates several parameters simulated by the models, including hydrography (SST and SSS) and the carbon cycle (represented by alkalinity, pCO_2, buffer capacity, and the CO_2 flux), to investigate the main drivers of the simulated changes.

REFERENCES

Pérez, F. F., H. Mercier, M. Vazquez-Rodriguez, P. Lherminier, A. Velo, P. C. Pardo, G. Roson and A. F. Rios (2013), Atlantic Ocean CO_2 uptake reduced by weakening of the meridional overturning circulation, Nature Geoscience, 6(2), 146-152.

Sabine, C. L., et al. (2004), The ocean sink for anthropogenic CO_2, Science, 305(5682), 367-371.

Skjelvan, I., E. Falck, F. Rey, and S. B. Kringstad (2008), Inorganic carbon time series at Ocean Weather Station M in the Norwegian Sea, Biogeosciences, 5(2), 549-560.

ATLANTIC HEAT CONSTRAINS **ARCTIC SEA ICE EXTENT**

Researchers from the Bjerknes Centre for Climate Research have for the first time quantified how Atlantic heat influences the sea-ice extent in the Barents Sea, where the retreat in Arctic winter sea ice is the most pronounced.

The study, published in the Journal of Climate, shows that interannual variability and a long-term decrease in sea-ice cover reflect changes in the inflow of Atlantic water.

Measurements from the southwestern Barents Sea and a numerical ocean model both reveal that increased heat associated with Atlantic water leads to a larger area with no wintertime freezing. The authors thereby confirm and detail a concept that was originally hypothesized by the two pioneers of modern oceanography, Bjørn Helland-Hansen and Fridtjof Nansen, more than 100 years ago.

Most of the sea-ice retreat is thus not ice that has melted – this would-be sea ice never froze – and is therefore a fundamentally different process than the observed summer sea-ice retreat in the central Arctic.

REFERENCE

Årthun, M., T. Eldevik, L. Smedsrud, Ø. Skagseth, and R. Ingvaldsen, 2012: Quantifying the influence of Atlantic heat on Barents Sea ice variability and retreat. J. Climate, 25, 4736–4743.

LONG-TERM TEMPERATURE VARIABILITY IN THE NORTH ATLANTIC INFLUENCES BIOLOGICAL PRODUCTIVITY AND SPECIES DISTRIBUTIONS

Changes in the marine productivity and its distribution within the northern North Atlantic covary with ocean temperatures on multidecadal time scales.

In the North Atlantic, observed multi-decadal temperature variability with a period of 60 to 80 years has been labeled the Atlantic Multidecadal Oscillation or AMO. It includes the cold period at the beginning of the 1900s, a warm period from about 1920 to the 1960s, followed by another cool period, and then the recent warming that generally began in the late 1980s or early 1990s. Although the exact cause of this temperature variability is uncertain, the most accepted hypothesis is that it is linked to the large-scale ocean circulation pattern in the Atlantic, specifically the Atlantic Meridional Overturning Circulation (AMOC). The AMOC includes the flow of warm water northward, its cooling and eventual sinking in northern latitudes, and its return flow southward at depth. Bjerknes scientists recently showed that volcanoes also might play a role in defining the AMO pattern. Paleo-oceanographic studies have shown this multidecadal temperature variability can be traced back at least 350 years.

Ken Drinkwater

An AMO index has been defined as the average sea-surface temperature anomaly over the North Atlantic Ocean with the long-term mean trend removed. The amplitude of this AMO index is small, only about ±0.2ºC from maximum to minimum. In spite of this, marine productivity and species distributions in the North Atlantic show temporal patterns remarkably similar to that of the AMO. The abundance of Atlantic cod off West Greenland, Iceland and Norway increased dramatically during the warm period in the middle of the 1900s and their distribution spread northwards, by upwards of 1500 km off Greenland. More spawning occurred to the north and in some instances new spawning sites were established. Higher growth rates led to larger size fish. Herring, capelin and other commercial species showed similar responses to cod and invasive species entered northern waters from the south. When the warm period gave way to cooling, the fish abundances in the North Atlantic decreased, growth rates fell and the fish retracted farther south. With the return to warm conditions more recently, the commercial fish responses were not identical to the early warm period, a difference that is believed to be owing to the effects of fishing. The cause of the changes in fish productivity is believed to be related to the variability in the phytoplankton and zooplankton, with higher plankton production during the warm phases of the AMO. Also, it is believed that the biological changes are not responding just to the small temperatures changes in the AMO but rather associated changes, perhaps in the ocean circulation, vertical stratification or nutrient fluxes.

REFERENCE

Drinkwater, K.F., Miles, M.W., Sundby, S., Kristiansen, T., Medhaug, I., Otterå, O.H., Gao, Y., Suo, L., Drange, H. Atlantic Multidecadal Oscillation: its manifestations and impacts with special emphasis on the region north of 60°N. Journal of Marine Systems. (In preparation).

WARMER BALTIC SEA MAY PROMOTE HARMFUL ALGAL BLOOMS

Massive blooms of so-called cyanobacteris, also known as blue-green algae, have been observed in recent years. Increased supply of nutrients from intensive agriculture, primarily phosphorus and nitrogen is considered a likely cause, but temperature changes in the surface waters of the Baltic Sea have also been implicated.

A group of scientists have now found that temperature is a major player in addition to nutrients, and that rising temperatures have been part of the increasing problem. This implies that continued warming is expected to exacerbate the problems.

By using sediment cores covering the last 1000 years of sedimentation in the Baltic, scientists unravelled warm periods in the past that were also characterised by algal blooms and low oxygen content. The study goes back to the Medieval warm period 1000 to 800 years ago.

REFERENCE

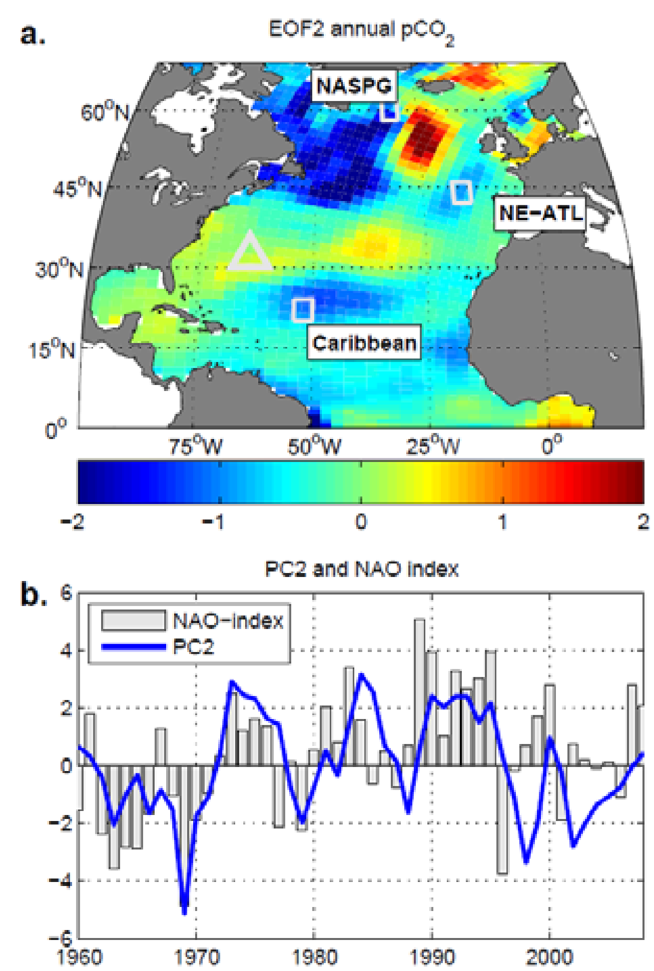
Karoline Kabel, Matthias Moros, Christian Porsche, Thomas Neumann, Florian Adolphi, Thorbjørn Joest Andersen, Herbert Siegel, Monika Gerth, Thomas Leipe, Eystein Jansen and Jaap S. Sinninghe Damsté, Impact of climate change on the Baltic Sea ecosystem over the past 1,000 years, Nature Climate Change (2012) doi:10.1038/nclimate1595.

WHAT CAUSES THE VARIABILITY IN AIR–SEA CO_2 FLUXES AND CAN WE SIMULATE THEM?

What causes seasonal-to-decadal changes in oceanic uptake of the greenhouse gas carbon dioxide?

Jerry Tjiaputra

The research group on biogeochemical cycles employed a complex coupled physical-biogeochemical model in conjunction with observations in order to: (i) test whether the model can reproduce variations in the carbon cycle as documented by direct observations, and (ii) to attribute the simulated changes to specific processes (Tjiputra, J.F., A. Olsen, K. Assmann, B. Pfeil, and C. Heinze, 2012: A model study of the seasonal and long–term North Atlantic surface pCO_2 variability, Biogeosciences, 9, 907–923). The model was used over the past 50 years (1960–2008) and was driven by observed synoptic (continuously changing) realistic atmospheric forcing. The simulated surface CO_2 partial pressure agrees well with recent underway pCO_2 observations from the Surface Ocean CO_2 Atlas (SOCAT) for different regions of the North Atlantic. This applies for the model's ability to simulate both the seasonal cycle as well as recent trends in air–sea CO_2 fluxes. For the longer time window of the years 1960–2008, the primary signal of surface pCO_2 variability is determined by the invasion of anthropogenic CO_2 into the ocean synchronous to the increasing CO_2 concentration in the atmosphere. It could be shown that the spatial variability structure of the dominating trend can – to a large extent – be explained by the surface ocean circulation and the associated air–sea heat flux pattern. Oceanic domains with surface convergence (and hence downwelling) and mean positive air–sea heat flux such as the subtropical gyre and the western subpolar gyre are marked by a higher long-term surface average CO_2 partial pressure than other regions. One of the most dominant variability patterns of the climate system is the North Atlantic Oscillation (NAO). This variability pattern not only governs the temporal and spatial structure of physical variables in the North Atlantic region but consequently also the variability of the ocean carbon cycle. The North Atlantic surface CO_2 partial pressure field is strongly influenced by the physical NAO signal through changing water-mass properties and hence local modifications of the solubility and buffering capacity for CO_2 in seawater. Here seawater temperature variations play the most important role. The modelling study clearly shows that the combination of continuous underway observations of the sea-surface CO_2 partial pressure and ocean models is extremely useful for: (i) calibrating the model with respect to the real world, (ii) increasing our understanding of the regional variability in ocean surface CO_2 content, and (iii) predicting and detecting changes in the oceanic uptake strength for human-produced CO_2.



The second most important spatio-temporal variation pattern of the North Atlantic surface CO_2 partial pressure (after the CO_2 increase in the atmosphere itself) is governed by the NAO. (a) Spatial variability pattern and (b) corresponding principal component. The simulated variability closely follows the observed NAO index.

REFERENCE

Tjiputra, J.F., A. Olsen, K. Assmann, B. Pfeil, and C. Heinze, 2012, A model study of the seasonal and long–term North Atlantic surface pCO_2 variability, Biogeosciences, 9, 907–923.


PHOTO: BJØRN KVISVIK

Centre for Climate Dynamics

The Centre for Climate Dynamics at the Bjerknes Centre (SKD) is a research and expertise centre for the advancement of the climate science, funded by a grant from the Ministry of Education and Research for the period 2010–2021. SKD is an integrated activity of the Bjerknes Centre, hosted by the UiB and organised as an independent unit within the university with its own board.

SKD CENTRE FOR CLIMATE DYNAMICS AT THE BJERKNES CENTRE

In 2012 the SKD core group became fully staffed with the employment of four research leaders with expertise in atmospheric and oceanographic dynamics, paleoclimate and marine biogeochemistry. By the end of the year, the core group and the first graduate students moved into brand-new offices, co-located with the Geophysical Institute. SKD acknowledges the UiB for the provision of top modern facilities and excellent working conditions.

Michael Schulz (left), Jens Hesselbjerg Christiansen, Anny Cazenave and Detlef Stammer attended the SKD days 2012 in Bergen.
PHOTO: GUDRUN SYLTE

In November the SKD Days were organised for the second time. This is a two-day event where the international Scientific Advisory Council (SAC) is invited to Bergen to meet with the SKD scientific environment. Project coordinators reported of main outcomes from their research to SAC members Anny Cazenave, Centre National d´Etudes Spatiales, Jens Hesselbjerg Christensen, Danish Climate Centre, Michael Schulz, University of Bremen and Detlef Stammer, University of Hamburg. The council then provided valuable feedback and concrete advice to the individual projects as well as to the SKD´s strategic research in general. Highlights from SKD research are presented here:

CONTRIBUTION TO INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)

INSTITUTIONS AND STAFF INVOLVED

UiB:
Asgeir Sorteberg (leader), Camille Li, Ilker Fer, Peter M. Haugan, Nils G. Kvamstø, Erlend M. Knudsen, Kerim Nisancioglu, Benjamin Pfeil, Dhanya Pushpadas, Corinna Schrum, Anders Sirevaag, Silje Sørland, Ellen Viste

Uni Research:
Mats Bentsen, Eystein Jansen, Petra Langebroek, Odd Helge Otterå, Lars H. Smedsrud, Jerry Tjiputra, Zhongshi Zhang

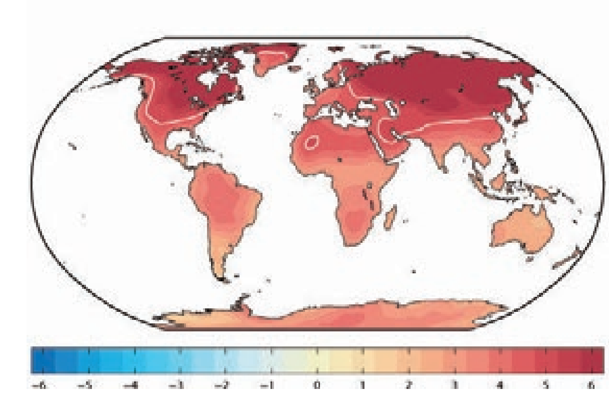
NERSC:
Igor Ezau, Yongqi Gao, Florian Geyer, Helene Langehaug, Svetlana Sorokina, Lingling Suo

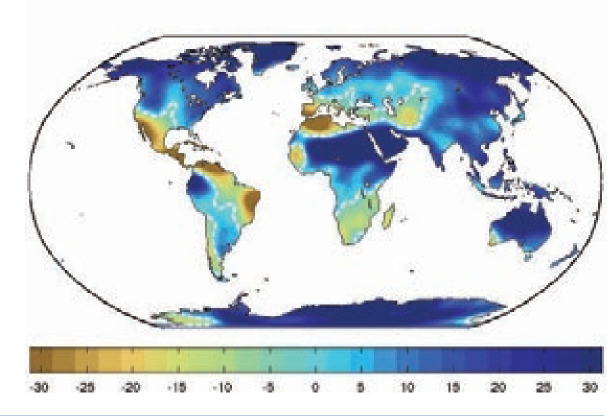
IMR:
Ken Drinkwater, Anne Britt Sandø, Svein Sundby

SKD partially funds research activities for the development of the global fully coupled *Norwegian Earth System Model* (NorESM), whose simulations contribute to the *Coupled Model Intercomparison Project Phase 5* (CMIP5), constituting the backbone of the upcoming 5th IPCC Assessment Report (AR5). SKD's grant also supports personnel within the Bjerknes Centre involved in the writing process of the AR5 who have been appointed Lead and Review Authors.

The NorESM family of models now consists of three members: (i) The coupled atmosphere–ocean–land-ice model – NorESM1-M – which can be run with prescribed greenhouse-gas concentrations, (ii) the fully coupled NorESM1-ME with biogeochemistry to describe the full carbon cycle so that the model can run with prescribed greenhouse-gas emissions instead of prescribed atmospheric concentrations, and (iii) a coarse resolution version – NorESM1-L – suitable for millennial-scale studies of past climates. SKD funds the development of all three components as well as simulations and analyses, through nine scientific work packages with focus on the arctic climate. Simulations for the last glacial maxima, present day and future century have been performed, while substantial model development of key ocean processes and the carbon cycle is well underway. The NorESM group was among the first to deliver data to the CMIP5 portal, and NorESM is one of the most frequently cited models in the literature (data used in more than 180 studies).

Changes in annual temperature (°C) (upper map) and precipitation (%) (bottom map) from present-day (1961–1990) to the end of the century (2071–2100) using the NorESM1-M with emission scenario RCP8.5. The solid white line indicates where the temperature change is 5°C and the white dashed line where there is no change in the precipitation.





STRATEGIC THEMATIC AREAS AND RESEARCH ACTIVITIES

Leader:
Odd-Helge Otterå

Strategic thematic area:

Natural and anthropogenic climate changes

Research project:

Integrated model-data approach for understanding multidecadal natural climate variability – IMMUNITY

INSTITUTIONS AND STAFF INVOLVED

Uni Research:
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Øyvind Lie, Martin Miles

UiB:
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Tor Eldevik, Noel Keenlyside,
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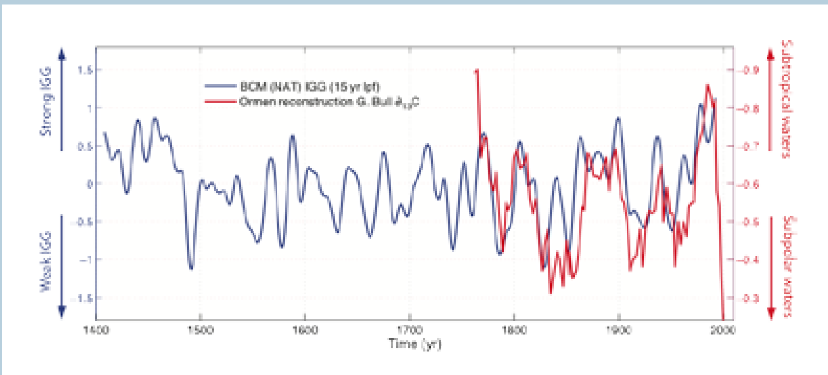
Øystein Skagseth

IMMUNITY integrates new, high-resolution palaeoclimatic time series and instrumental data with long simulations with climate models in order to explore long-term climate variations during the last 1500 years. The project has made substantial progress in terms of reconstructing key ocean state variables in the northern North Atlantic during the last millennium. In particular, the multi-proxy records from existing cores at the Eirik and Gardar drifts are being extended further back in time to cover the last two millennia.

A new approach will allow testing the validity of the Gardar Drift as a proxy for the variability of the overflow water exiting through the Iceland–Scotland Ridge in the framework of climate modelling. The main aim is to investigate if the Gardar Drift can be realistically represented in the Bergen Climate Model (BCM) and, if so, to what extent one can pinpoint a locality in the model along the Reykjanes Ridge that realistically represents the actual variability of the overflow on the Iceland–Scotland Ridge. Ultimately, the model will be used to explain the governing mechanisms of the variable ridge overflow and how it relates to known climate perturbations like the North Atlantic Oscillation (NAO) and the Atlantic Multidecadal Oscillation (AMO). In addition, ultra-high resolution paleo records from the Nordic Seas reflecting relative contributions of sub-tropical and sub-polar waters are being compared to a 600-year historical run with BCM. The paleo record show a remarkable similarity to simulated intergyre gyre circulation in the North Atlantic over the last 300 years, highlighting the potential crucial role by the North Atlantic Oscillation (see figure). A synthesis of available historical sea-ice observations has also been conducted identifying signals of persistent multidecadal variability in sea-ice data back in time, which appear closely linked to the AMO.

On the terrestrial side, we are also developing novel methods for tracking changes in palaeo-precipitation and palaeo-wind along the western coast of Norway and Svalbard. For this purpose, a sediment core from a lake at Andøya close to a large sandy beach will be used. By analysing the concentration of silicium in the sediments, a proxy for beach sand flux, one could make inferences of storm frequency at the site.



Model-data comparison in IMMUNITY. Simulated intergyre Gyre index in the natural forced simulation with BCM (blue), reconstructed water-mass characteristics from the Ormen site in the Nordic Seas based on G. bulloides 13C (red).

Leader:
Tor Eldevik

Strategic thematic area:

Process understanding and uncertainties

Research project:

Predictability of Arctic/ North Atlantic climate – PRACTICE

INSTITUTIONS AND STAFF INVOLVED

UIB:
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Uni Research:
Mats Bentsen, Ingo Bethke, Odd Helge Otterå

NERSC: Laurent Bertino, François Counillon, Jan Even Ø. Nilsen

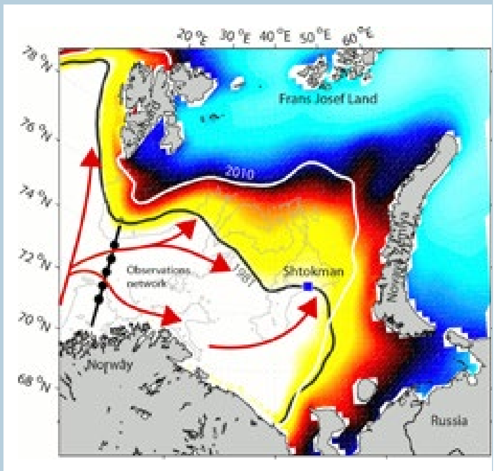
IMR:
Kjell Arne Mork, Anne Britt Sandø, Øystein Skagseth

It is unknown to what extent climate is predictable – both from a theoretical and a practical perspective. It is nevertheless a premise that *to constrain future climate, one must be able to constrain the (observed) past and present*. With respect to constraining regional climate on interannual to decadal climate time scales, the potential for prediction is understood largely to reside in the inertia and relatively slowly varying heat content of the ocean (Skagseth and Mork 2012). *PRACTICE* thus assesses predictability from a northern and marine perspective; the former for two related reasons: First because this is the climate we live in and the seas we harvest from, and second, the Nordic and Barents seas are among the most well-observed regions of the world oceans as a result of not only very rich fisheries but also decades of 'cold war'.

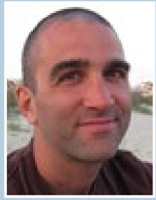
Observations are continuously assimilated into a climate prediction model to align the model with the observed state of the ocean up to the point of prediction. When skillful, the model will simulate future climate realistically as long as the model remains true to the memory imprinted on it from observations and until chaotic dynamics drive it off course. Such a model – the Norwegian Climate Prediction Model (NorCPM) – has been developed within *PRACTICE* (Counillon et al. 2013). NorCPM is now in its evaluation and refinement phase. Test results show that the skill in modelling future sea-ice concentration and hydro graphy of the northern seas, for instance, will be improved when observations are assimilated. In parallel, the project scrutinizes the observational record to reveal mechanisms of predictive potential that appear robust. The paper of Årthun et al. (2012) is a timely example (see figure). Here it is shown how the Atlantic inflow to the Barents Sea and northern winds are causal in setting the winter sea-ice extent. This is key both to assess the issue of northern climate predictability from first principles and to provide a sound framework for evaluating NorCPM performance.

[Please note: an estimate that there will be a global warming trend of, say, 0.3°C per decade through this century is a projection; the skillful regional and temporal climate modelling of the variability superimposed on this trend constitutes a prediction].

Reference:
Årthun, M., T. Eldevik, L.H. Smedsrud, Ø. Skagseth, and R. Ingvaldsen, 2012: Quantifying the influence of Atlantic heat on Barents Sea ice variability and retreat. J. Climate, 25, 4736–4743.
Counillon, F., I. Bethke, N. Keenlyside, M. Bentsen, L. Bertino, and F. Zheng, 2013: Seasonal-to-decadal prediction with the EnKF and NorESM: a twin experiment. To be submitted to Tellus.
Skagseth, Ø. and K.A. Mork, 2012: Heat content in the Norwegian Sea, 1995–2010. ICES J. Mar. Sci., 69, 826-832.



Main pathways of Atlantic water (red arrows) and Barents Sea winter ice concentration between 1979 and 2010 (colour map). Contours are winter ice extent for the winters 1981 and 2010. Note how the Shtokman gas field would be exposed if the sea returns to a state like the 1980s. Figure courtesy of Marius Årthun.

Leaders:
Bjørn Ådlandsvik &
Stefan Sobolowski

Strategic thematic area:

Regional climate scenarios and extremes

Research project:

Regionalisation of climate scenarios – REGSCEN

INSTITUTIONS AND STAFF INVOLVED

IMR:
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Stefan Sobolowski (co-leader), Martin King, Muralidhar Adakudlu, Stephanie Mayer

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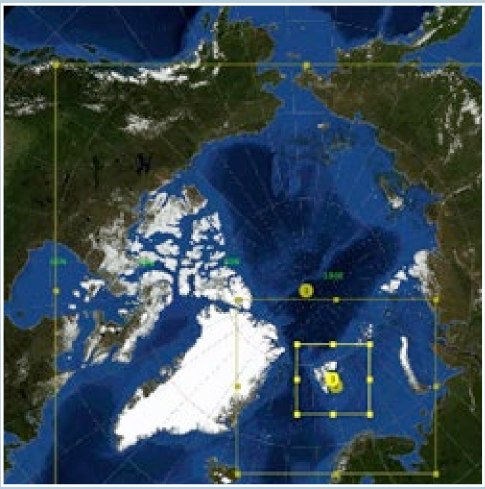
NERSC:
Jon Bergh, Igor Ezau, Yiwen Xi

The downscaling activities under *REGSCEN* include atmospheric and oceanic components. Atmospheric scenarios are used to assess climate change at the regional scale while the resultant marine scenarios are used to assess impacts of regional climate change on biological production and the carbon cycle. Since dynamical downscaling adds another layer of uncertainty to the global climate projections, *REGSCEN* will evaluate the performance of the methodology and thus make a contribution to the climate research community at large. Although climate change is global, what matters to ecosystems and societies are regional impacts and local consequences, so the primary interest is to plan for response to climate changes at the spatial scale of the ecosystems and human activities.

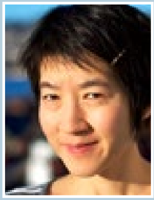
REGSCEN is developing a statistical–dynamical downscaling method applicable to the weather and climate analysis over very complex terrain where the local effects are expected to predominate over large-scale variability. For the dynamical part of the work, focus has been on downscaling of climate runs from the relatively coarse resolution Norwegian Earth System Model (NorESM) using the Weather Regional Forecast (WRF) model down to a resolution of 1 km. In one study, the model domain was centred in the Bergen–Hardanger region at the west coast of Norway. The turbulence-resolving model PALM has been used for Kongsfjorden at Svalbard and for Hardangerfjorden, as well as for urban downscaling and air-pollution studies in Bergen and surrounding areas. Results show that the local climate variability is indeed dominated by the local factors and relatively insensitive to the large-scale variability.

A new modelling system denoted Polar COAWST[1] has been developed under the auspices of *REGSCEN*. This is a system of coupled regional models including a newly developed ice model (CRIM), the Ocean Modelling System (ROMS) and the WRF atmospheric model. Polar COAWST was tested in the Svalbard region at high resolution (2.4 km) and showed that explicitly resolved topography around Storfjorden resolves the process of polynya formation and development in a much more realistic way compared to previous uncoupled model systems where the ice–ocean model was forced by coarse (200 km) resolution atmospheric reanalysis fields. Polar COAWST is currently being validated for atmosphere–ice–ocean processes in the Storfjorden region of Svalbard, using field observations from 1999–2003.



The nested Polar COAWST domains.

1) Coupled Ocean–Atmosphere–Wave–Sediment Transport (COAWST) model system.




Leaders:
Camille Li & Bjørg Risebrobakken

Strategic thematic area:

Climate sensitivity and thresholds

Project:

Dynamics of past warm climates – DYNAWARM

INSTITUTIONS AND STAFF INVOLVED

UiB:
Camille Li (co-leader), Hillary Birks, John Birks, Catharine Jenks, Helga Kleiven, Ulysses Ninnemann, Kerim Nisancioglu

Uni Research:
Bjørg Risebrobakken (co-leader), Carin Andersson Dahl, Eystein Jansen, Petra Langebroek, Lars H. Smedsrud, Zhongshi Zhang

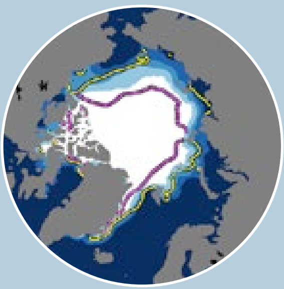
NERSC:
Igor Ezau

Warm climates have dominated the past 65 million years of Earth history. Understanding why these past warm climates existed is critical for understanding the consequences of current and future global warming. *DYNAWARM* investigates how warm conditions on Earth are created and maintained by combining reconstructions of past warm climates, global model simulations of past and future warming, and studies of the physical processes contributing to polar warmth to answer questions such as:

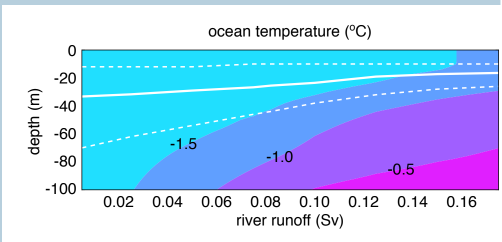
1) Are there thresholds in the climate system as it warms, and if so, are the changes as we cross these thresholds irreversible?
2) What can the paleoclimatic records reveal about the dynamics of past warm periods?
3) What controls the long-term, natural climate variability of the Polar Regions?

Activities at *DYNAWARM* range from examining shifts in polar biota and ecosystems during past warmings to studying how interactions between components of the climate system generate warmer and cooler periods in global models. Of the numerous warm climate periods in the geologic record, the Pliocene (5.3–2.6 million years ago) has a particular focus because it represents an equilibrium analogue for the present climate (CO_2 concentrations similar to those expected at the end of this century and global mean temperatures 3°C warmer than today). Important goals are to reconstruct polar and subpolar ocean temperature records and tropical ocean dynamics in a realistic way.

A fundamental component of *DYNAWARM* concerns potential thresholds in the cryosphere, both sea ice and ice sheets. Arctic sea ice cover has been declining under global warming, and some climate model simulations suggest that it could disappear altogether in the future. *DYNAWARM* researchers are investigating some of the factors that could accelerate or slow this decline using a process model of an Arctic ocean-sea ice-atmosphere column. For example, river runoff into the Arctic Ocean is expected to increase in a warming world. In the column model, increasing runoff has interesting, disparate effects. It reduces the vulnerability of the ice cover by freshening the protective surface layer; at the same time, the surface layer thins and the underlying warm Atlantic layer shoals, bringing more heat closer to the base of the ice.



Sea ice retreat simulated by the Norwegian Earth System Model (NorESM). Colour shading shows mean September ice concentration over the 1990s in the historical run. Contours show the projected September ice cover (15 % concentration) in 2100 under emission scenarios RCP2.6 (yellow) and RCP6 (pink). Emission scenario RCP8.5 simulates virtually ice-free September conditions in 2100.



Effect of increasing river runoff on the Arctic Ocean in an ocean-ice-atmosphere column model. Colour shading shows ocean temperature in the top 100 m of the column model. White lines indicate the depth of the mixed layer (solid) and its seasonal range (dashed). Recent estimates of runoff from rivers into the Arctic are in the 0.08 Sv range.

Leader:
Jan Even Ø. Nilsen

Strategic thematic area:

Past, present and future changes in sea level

Research project:

Sea level change and ice sheet dynamics – SEALEV

INSTITUTIONS AND STAFF INVOLVED

NERSC:
Jan Even Ø. Nilsen (leader), Linling Chen, François Counillon, Kirill Khvorostovsky, Johnny A. Johannessen, Ola M. Johannessen, Victoria Miles, Stein Sandven, Qing Yan.

UIB:
Helge Drange, Ilker Fer, Anna Hughes, Øystein Lohne, Jan Mangerud, Sönke Maus, Atle Nesje, Kristin Richter, John Inge Svendsen, Kristian Vasskog

Uni Research:
Mats Bentsen, Martin Miles

IMR:
Lars Asplin, Paul Budgell, Mari Myksvoll

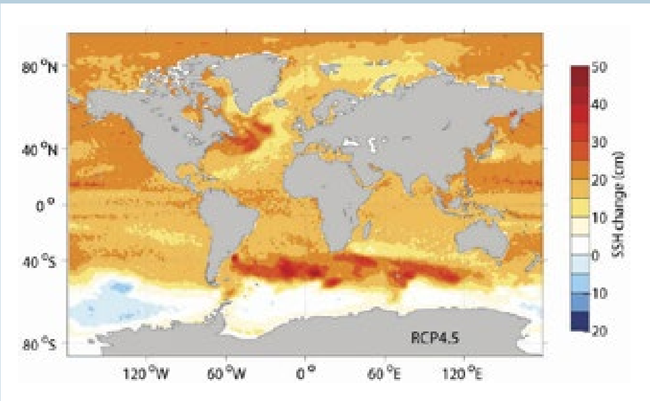
SEALEV is designed to understand past and present changes in the Greenland Ice Sheet (GrIS) and to project future rates of sea-level rise under climate change, for the Norwegian as well as for other coastal regions. There is a strong focus on the processes within the ice sheet and atmospheric accumulation on top, as well as deliverance of mass (freshwater) to the ocean. Regarding regional sea-level rise, *SEALEV* has a strong observational basis, combining ocean density with remotely-sensed sea-surface height and gravity, to assess the combined effect of mass exchange, steric changes and ocean dynamics on sea-level rise across the oceans. The geology work package will quantify past changes in sea level and ice sheets including the vertical movement of the Earth's crust. A consistent system to improve sea-level projections in the 21st century is ensured by a strong core of modelling activity.

During 2012, several advances were made. The merging and validation of satellite data to derive time series of surface elevation of the GrIS reveals an overall increase since 1992, but a negative trend since 2006. The studies of accumulation and runoff show a strong reduction in summer precipitation, which leads to melting enhanced by the lowering of surface albedo, while air temperatures are increasing year-round. High-resolution records of outlet glacier advance and retreat with unprecedented multidecadal coverage reveal strong variability and a general retreat of southeast Greenland's Sermilik Fjord glaciers. The fjord-to-ocean modelling was improved with a new coupled model setup with finer-scale modules of the ocean, atmosphere and ice shelf. Furthermore, ice-sheet models forced by CMIP5 runs, project a Greenland contribution to global sea level rise between 6.5 and 7.1 cm by 2100.

Present sea-level change along the coast of Norway was assessed and the main contributors to the positive trends are warmer waters and the worldwide melting of land ice, with approximately equal importance.

A database of paleo sea-level observations in the area affected by the Eurasian Ice Sheet was developed. A key finding is that during the Early Holocene, outlet glaciers in Hardangerfjorden and Sognefjorden, similar to present-day Greenland outlet glaciers, retreated up to 350 meters per year. The DATED database of the Fennoscandian Ice sheet area and volume during the past 25 000–10 000 years was also developed.

A full set of CMIP5 simulations was finalized with NorESM, with implementation of freshwater fluxes quantified as mass. The simulations for the 21st century quantify, and clearly demonstrate, how thermal expansion in the lower layers of the North Atlantic and Arctic Ocean will lead to increased mass on shallow shelves, and by gravity changes lead to self-attraction and loading effects there. The latter are estimated to be rather small, with a maximum effect of 3 cm, in the Barents Sea.



Change in sea surface height due to steric height changes and redistribution of seawater during 21st century as projected by NorESM-M under the RCP4.5 scenario. Global average change is 18 cm.

Leader:
Christoph Heinze

Strategic thematic area:

The carbon cycle and the marine ecosystem

Research project:

Biogeochemical feedback in the climate system – from processes to large-scale effects – BIOFEEDBACK

INSTITUTIONS AND STAFF INVOLVED

UiB:
Christoph Heinze (leader), Helle Botnen, Ute Daewel, Helene Frigstad, Friederike Hoffmann, Solveig Kringstad, Nadine Goris, Truls Johannessen, Tor de Lange, Siv Lauvset, Are Olsen, Benjamin Pfeil, Corinna Schrum, Ingunn Skjelvann, Jörg Schwinger, Frede Thingstad

Uni Research:
Emil Jeansson, Aud Larsen, Abdirahman Omar, Anna Silyakova, Caroline Roelandt, Jerry Tjiputra

IMR:
Christoph Bernard, Solfrid Hjøllo, Geir Huse, Morten Skogen, Henrik Søiland

NERSC:
Laurent Bertino, Kjetil Lygre, Annette Samuelsen, Ehouran Simon.

BIOFEEDBACK will quantify the expected changes of global and regional marine and terrestrial coupled cycles of carbon, nutrients and oxygen, taking into account multiple drivers such as increasing greenhouse-gas emissions, ocean acidification, warming, changes in circulation, as well as stratification and de-oxygenation. The approach combines new data archaeology, database synthesis, model development and decadal to centennial model simulations with rigorous model performance evaluations to provide new system understanding.

The 2012 progress plan was accomplished and the project is on track. The work carried out so far provides a sound foundation for the testing and evaluation of new feedback processes in the next phase. Highlights of the activities carried out:

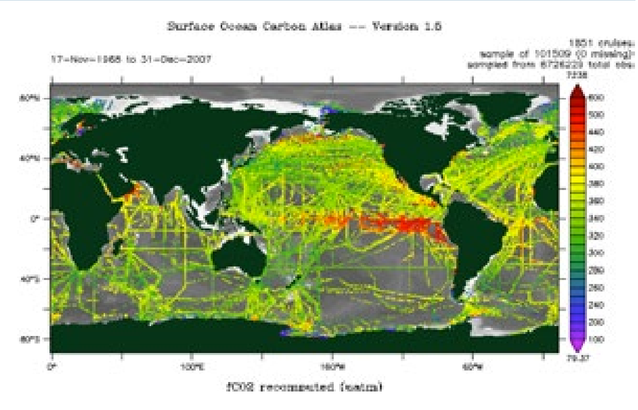
A workshop was carried out to rank the various climate–carbon cycle feed back processes in order to prioritise specific processes for further research. One of the strongest feedbacks would be the potential carbon overconsumption ("Redfield ratio change") during biological particle production at the sea surface. However, the uncertainties related to its existence, climate dependence and actual strength are large and needs better constrain before implementation in the Norwegian Earth System model (NorESM) is considered.

A collation of observational data sets and data syntheses for evaluation of global and regional models was assembled, as the foundation for a rigorous performance assessment and for the EnKF data assimilation procedure for HAMOCC. The database includes surface and deep carbon observations and related tracers, as well as experimental data from mesocosm experiments and primary production data.

A method for the bias correction of total alkalinity (TA) and total dissolved inorganic carbon (TCO2) was successfully tested with the biogeochemical ocean general circulation model HAMOCC2s.

A complete set of climate runs, including future scenarios, was carried out with the NorESM including interactive carbon cycle for both land and ocean. A sub-set of runs was repeated including riverine delivery of matter. Further, a method for including the effect of changing permafrost areas was initiated.

A set of model integrations with the NORWECOM model system was carried out for the northern North Atlantic Ocean. A particular challenge was the prescription of the biogeochemical as well as physical fields at the open model boundaries from the global GISS Earth system model plus selected observational data sets.



Spatial data coverage of sea-surface CO2 fugacity (subsampled fCO2, 4 times daily; from SOCAT Version 1.5) used in the model evaluation.

Reference: Pfeil, B., A. Olsen, D.C.E. Bakker, S. Hankin et al., 2012. A uniform quality-controlled Surface Ocean CO2 Atlas (SOCAT). Earth System Science Data Discussions, 5: 735-780

OUTREACH AND MEDIA HIGHLIGHTS

RISING TREND OF MEDIA INTEREST

The Bjerknes Centre is experiencing a rising interest in climate issues in the media and in the public. In comparison with 2010, media interest and media coverage of the Bjerknes Centre and climate issues have had a significant increase.

The drop of interest in 2010 is commonly explained by the lack of political action and failure of COP 15 in Copenhagen in December 2009, combined with the global financial crisis. We are now experiencing a rising interest. Our scientists are highly sought after for invitations to give popular science talks, and the Centre and the scientists receive many invitations to contribute our climate knowledge to various social arenas.

TWITTER

The Bjerknes Centre went on Twitter in autumn 2011. In December 2011, Eystein Jansen started tweeting from @BjerknesBCCR. By January 2012, we had 87 followers and a year later the number of followers had expanded to over 700. Many Bjerknes scientists are also now on Twitter sharing climate information and more private opinions.

TWO DEGREES – A NEW ANNUAL MAGAZINE ABOUT CLIMATE

In November 2012 a new climate magazine and website was launched by the Norwegian Climate Foundation in collaboration with the Bjerknes Centre, who delivered much of the contents. The magazine is named 2°C, and we aim for this to be a magazine which is produced annually, to serve as a reference document on climate science for opinion-makers, politicians, stakeholders and NGOs in support of their need for precise and updated information from climate research.

The Bjerknes Centre is responsible for the climate information and knowledge in the magazine, while the Norwegian Climate Foundation is the publisher and has raised funds to establish the magazine. The Ministry of Environment together with businesses and organisations have sponsored the issue. 2°C is also approved as a commitment by the Clinton Global Initiative.

Please check out tograder.no and twodegrees.org.

ANNIVERSARY YEAR

In 2012 it was ten years since the Bjerknes Centre became one of the 13 first National Centres of Excellence, a concept initiated by the Research Council to stimulate Norwegian research institutions to establish visible, long-lasting research centres at a high international level. 2012 was therefore an anniversary year for the Bjerknes Centre, which was marked with several activities. The largest of these was our anniversary conference in the beginning of September, "Climate Change in High Latitudes".

The conference gathered over 200 climate researchers from all over the world, for three days loaded with scientific talks. In cooperation with the Student Council, we arranged a public session with talks by Bogi Hansen and Andrew Watson. The talks were followed by a discussion on the communication of climate science with a broad panel of climate researchers: Ray Bradley, Andrew Watson, Bogi Hansen, Eystein Jansen and Kjersti Fløttum. The session at The Academic Quarter was highly popular, a crowded room with over 160 participants.

On November 30, the last official day under the Centre of Excellence system, we arranged a well-attended open seminar, which summarized for a public audience the main findings of our research over the ten years across all of our activities.

From the left we see Bogi Hansen, Professor, Faroe Marine Research Institute; Andrew Watson, Professor, School of Environmental Studies - University of East Anglia; Eystein Jansen, Director, Bjerknes Centre for Climate Research; Raymond Bradley, Department of Geosciences and Director of the Climate System Research Center, University of Massachusetts Amherst; and Kjersti Fløttum, Professor, Department of Foreign Languages - University of Bergen

Eystein Jansen, Director at the Bjerknes Centre, speaking at the anniversary conference. PHOTO: EIVIND SENNESET

Kikki Kleiven, Tobias Thorleifsson and Marit Sjøvaag Marino went on tour educating high school teachers around the country.
PHOTO: FREDRIK NAUMANN

Thomas Spengler explains local meteorological phenomenons at Snøhetta for the visiting class from Støren high school. PHOTO: KERIM NISANCIOGLU

COOPERATION WITH SCHOOLS

Many scientists at the Bjerknes Centre have been involved in cooperations with schools during the year 2012.

In 2010 the Ministry of Education initiated the "Klimaklok" (Climate Wise) lecture tour consisting of Bjerknes Centre scientist Kikki Kleiven, Siri Kalvig – a nationally known meteorologist, and polar explorer Tobias Thorleifsson. The team visited schools in cities around Norway, educating high school teachers. The tour was a success, and by popular demand the Ministry of Education initiated a new tour, "Generation Green" for the autumn of 2012.

The new team consists of Kikki Kleiven, Tobias Thorleifsson and political scientist Marit Sjøvaag Marino from the Centre for Climate Strategy at the Norwegian Business School.

Helge Drange, Friedrike Hoffmann and Lars Henrik Smedsrud are answering questions from school youths at BIFF. PHOTO: GUDRUN SYLTE

In mid-October the three Bjerknes scientists Helge Drange, Lars Henrik Smedsrud and Friedrike Hoffmann entered the movie theatre where they engaged in interactions with some hundred youths from schools around Bergen who had seen the documentary "Chasing Ice". In cooperation with the annual Bergen International Film Festival (BIFF), a major event for documentary films, Drange, Smedsrud and Hoffman developed educational material for some of the climate films at the festival.

In late August the Advanced Climate Dynamics Courses (ACDC) leader, Kerim Nisancioglu, invited school classes and the general public to the Snøhetta mountain where the ACDC summer school was held this year. In cooperation with the School Laboratory at UiB, Nisancioglu developed "turspor" (trekking tracks), a track where the students and the public obtain information on nature and climate by following a mountain path with questionnaires and additional information on QR-codes.

NEW INITIATIVES, **EDUCATION AND COOPERATION**

Greg Holland and Eystein Jansen sign documents formalizing the Partnership. PHOTO: GUDRUN SYLTE

NEW PARTNERSHIP WITH NCAR

During our anniversary conference in September, the Bjerknes Centre and NCAR, the National Center for Atmospheric Research in Colorado, USA signed a Memorandum of Understanding (MoU) agreement. The partnership includes exchange of researchers, education and developing regional climate expertise and capacity in developing countries. For the younger Bjerknes scientists, this means opportunities for professional development obtained by exchange with the environment at NCAR.

"NCAR is perhaps the foremost specialist in climate modeling and climate dynamics. Their model systems are used worldwide. In the Norwegian Earth System model used for the next IPCC report, essential components were developed at NCAR. We also use their system for downscaling of climate simulations at regional and local scale." Eystein Jansen says.

Michel Mesquita, from Uni Research and the Bjerknes Centre, is the main driving force in the cooperation on the BCCR side, and has been in close contact with the NCAR community in recent years. The WRF model (Weather Research and Forecasting model), which is developed at NCAR, is used by climate researchers worldwide. NCAR and the Bjerknes Centre have together held WRF seminars in Bergen and in Bangkok. In the autumn of 2012, the two partners held two regional climate tutorials in Asia — one in Hanoi (Vietnam) and the other in New Delhi (India).

FUTURE CLIMATE EXTREMES IN THE CARIBBEAN

Cuba is expected to see stronger hurricanes and more drought episodes in future climate scenarios. Moreover, with an increasing population in an area that is prone to both hurricanes and drought, the vulnerabilities are even more challenging.

This year the Bjerknes Centre and the Cuban Institute of Meteorology (INSMET – Instituto de Meteorología) started a 3-year collaborative project on climate change research, sponsored by the Norwegian Embassy in Havana.

In May, Project Leader Michel Mesquita hosted seven Cubans in balmy Bergen for the official start of the project, called XCube, which is concerned with future climate extremes in the region.

INSMET's Research Director Abel Centella stated: "This research collaboration has many interesting aspects for us. The Meteorological Institute is responsible for the weather forecasting in Cuba and we will improve weather forecasting, especially at seasonal scale when it comes to hurricanes and drought. Through this project, we will increase our own capacity and quality and provide better services to the Cuban audience and the authorities. We hope this is the beginning of a long collaboration" .

As capacity-building is an important part of the research collaboration, Centella is looking forward to improving their knowledge of climate modeling for the benefit of their research.

Photographed from left: Ramon Perez (INSMET), Abel Centella (INSMET), Project Leader Michel Mesquita (Bjerknes Centre and Uni Research), Braulio Lapinel (INSMET), Israel Borrajero INSMET), Lourdes Alvarez (INSMET), Paolo Ortiz (INSMET), Juan Carlos Antuna (GOAC). PHOTO: GUDRUN SYLTE

INTERNATIONAL MEETINGS AND ENGAGEMENTS

INDIA KICK-OFF MEETING WITH PACHAURI AND SOLHEIM

On February 1, in New Delhi, Rajendra K. Pachauri and Erik Solheim opened the BCCR-TERI session "Indo-Norwegian Research Collaboration to address Climate Change Impacts on selected Indian Hydrological Systems using Earth System and High Resolution Modelling". This was a side event to the annual TERI conference Delhi Sustainable Development Summit. The NORINDIA research project is funded by the India programme of the Norwegian Research Council (with support from the Ministry of Foreign affairs) and SN Power. SN Power is owned by Statkraft and Norfund, who invest in hydropower in emerging markets with the aim to contribute to economic growth and sustainable development.

The NORINDIA project addresses future hydrological impacts in India, and the kick-off meeting included a round-table discussion with stakeholders to address their concerns in terms of water and energy management. One of the problems with hydrology research in India is access to data. Anuj Hanwal, from the Indian government, assured that they are trying to improve the situation.

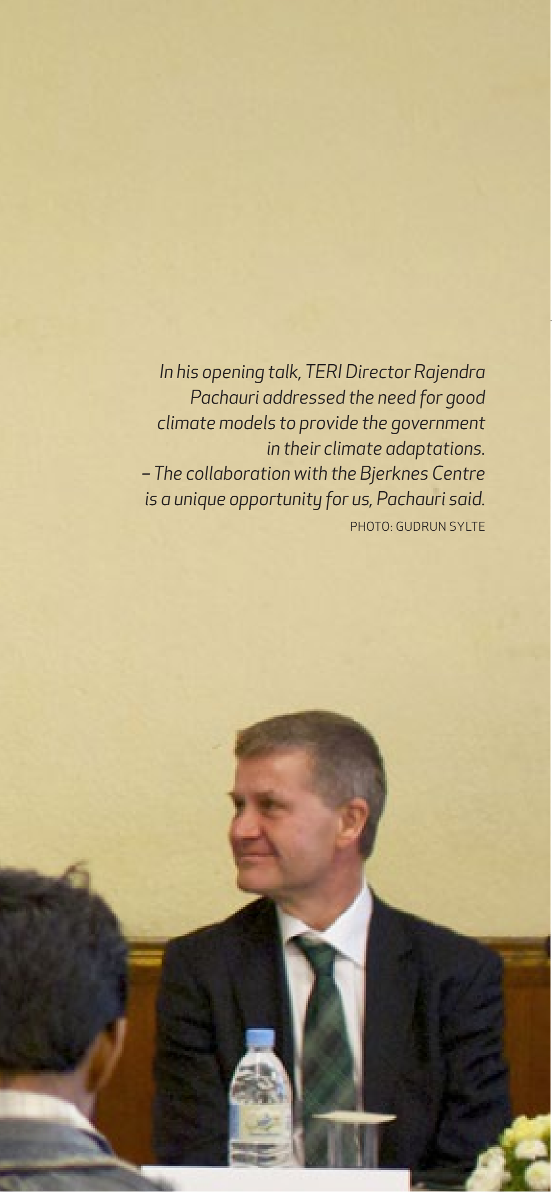
The project is a collaboration between the Bjerknes Centre, TERI-The Energy and Resources Institute, IITM-Indian Institute for Tropical Meteorology (Pune, India), CSIR-Centre for Mathematical Modelling and Computer Simulation (Bangalore, India), the University of Oslo, The Norwegian Institute for Air Research and SN Power.

OPENING WORKSHOP IN HANOI

The Bjerknes Centre and the Institute of Meteorology, Hydrology and Environment (IMHEN) in Hanoi, Vietnam started a 30- month long collaborative project in climate research in spring 2012. The Norwegian Ministry of Foreign Affairs sponsors the project through their embassy in Hanoi.

On February 27-28, Tore Furevik and Martin King travelled to Hanoi to attend the opening workshop. On the first day, they met with project scientists from IMHEN to discuss project tasks and various issues regarding regional climate downscaling for Vietnam.

Besides generating regional scale climate change projections for Vietnam, the project provides a great opportunity to study the east Asia monsoon – its variability, dynamics, and forcing mechanisms and extreme events, such as heavy rainfall and hurricanes, in the western Pacific area.



In his opening talk, TERI Director Rajendra Pachauri addressed the need for good climate models to provide the government in their climate adaptations.
– The collaboration with the Bjerknes Centre is a unique opportunity for us, Pachauri said.
PHOTO: GUDRUN SYLTE

TWO LARGE MEETINGS IN BERGEN IN TWO WEEKS

In late May the Scientific Committee of the IGBP (International Geosphere-Biosphere Programme) held their annual meeting in Bergen. This included an open seminar for Bergen scientists on biogeochemical cycles and sustainable development in the oceans, atmosphere and on land.

A week later the European carbon observation network ICOS (Integrated Carbon Observation System) gathered in Bergen for their annual meeting, including scientists, stakeholders and politicians.

ICOS tracks carbon fluxes in Europe and adjacent regions by monitoring the ecosystems, the atmosphere and the oceans through integrated networks. ICOS is established under the European Large Scale Infrastructure program, ESFRI, and is divided into three themes, Atmospheric, Ecosystem and Marine Observations. The first two are already up and running; while for the Marine Network, the Bjerknes Centre

ICOS at mount Fløyen. PHOTO: MIKKO STRAALENDORFF

is applying for funds together with NILU and BIOFORSK to establish a Norwegian node in the project, and also for funds to become a head-quarter for the Ocean Thematic Centre. The two other thematic centres are located in France and Italy.

SUMMER SCHOOL IN BEIJING

When most people in Norway were thinking about their summer vacation, fourteen Bjerknes scientists headed for Beijing and the fifth biannual summer school organized by the Nansen Zhu Centre. 15 lecturers and 40 PhD students and post-docs were gathered in the Chinese capital where they for more than a week focused on "Monsoon Variability and Climate Teleconnections".

The summer school consists of a combination of expert lectures, group work, student presentations and various social activities, such as excursions and extended dinners.

The University of Bergen, the Nansen Centre and UNI Research are partners in the Nansen Zhu collaboration.

A joint project meeting for the DecCen and BlueArc projects, coordinated by the University of Bergen and the Nansen Center, respectively, preceded the summer school. Despite challenges in the Sino Norwegian political relationship, the collaboration at the scientific level is a strong as ever, and a number of very interesting results are about to be published from the two projects.

ACDC AT DOVRE

This year in late August 70 highly qualified PhD students competed for the 25 places at the Advanced Climate Dynamic Courses (ACDC) Summer School at Dovre. Several months before the summer school, ACDC leader Kerim Nisancioglu received the good news that the summer school was allocated funds enough to run ACDC summer schools for four more years.

The partnership program between Norway and North America has allocated funds enough to run the ACDC summer school, educating a new generation of climate researchers. At the summer school, the young researchers are trained to understand more than just one discipline.

"With us, students can combine subjects across the traditional disciplines. This is unique and is something that one doesn't easily get organised within the University", Kerim Nisancioglu says.

The summer school also combines fieldwork with instruction. For example, Nisancioglu, who had recently been on Snøhetta to set up a number of measuring instruments to collect data for the summer school later in August, is considering expanding the summer school to have a field trip earlier in the year, and have the summer school half a year later. That way, candidates can try their hand at both the theory and practice.

With the new funding, there are also two new partners: the University of Massachusetts-Amherst and Memorial University of Newfoundland.

ASPIRING CLIMATE SCIENTISTS AT THE BJERKNES CENTRE

Helene R. Langehaug and Iselin Medhaug didn't intend to cooperate on their PhDs, it just happened – and both are happy that it did.

Helene R. Langehaug (left) and Iselin Medhaug have continued working at the Bjerknes Centre after they finished their PhDs. PHOTO: CAMILLA AADLAND

– My PhD was in physical oceanography. I reviewed the circulation in the North Atlantic, by using climate models. I wanted to understand what steers the different components of the circulation, Langehaug says.

They both used the same model run, but on different topics. Or so they thought.

–I heard a lecture from Helene, and discovered that she worked on the same problem, and had made the same figures as I did, so then we had to have a meeting immediately, Medhaug says.

The two scientists decided to cooperate, and both found that very useful and enjoyable.

–We had to work at the same speed because we had the same deadline, and we could discuss issues before we had to go to our mentors, Langehaug says.

VIRTUAL FLOATS

Iselin Medhaug focused on the vertical overturning of the Atlantic Ocean, while Helene's PhD was more focused on the horizontal circulation, the subpolar gyre.

Helene took her Master's in oceanography, while Iselin studied meteorology before she started on her PhD Both finished their PhDs during 2011, and have continued to work with climate research at the Bjerknes Centre.

–I started a post-doc position after last summer, and I work with the same topics. I use the same models, and study what the ocean circulation means for the heat transport. Everybody has heard about the Gulf Stream, but I want to find the mechanisms and meaning of the circulation. How much water does it bring, to which areas and how does it work, and what does it mean, says Medhaug.

Last year she spent at Imperial College London, a stay she found very useful.

–After ten years in Bergen it was good to get new impulses and ways of thinking, she says.

She's brought the new thinking into her research, and has now launched hundreds of virtual floats, to be able to say more about the circulation in the Arctic Ocean.

THE NEWEST IPCC CLIMATE MODELS

Helene has shifted focus a bit, and is now working more with arctic sea ice at the Nansen Environmental and Remote Sensing Center.

–We use the newest IPCC climate models, to see if the models are able to capture the observed trend and variability of the sea ice, she says.

Both of them want to continue with science, particularly with climate research.

–I hope that I can contribute to bring forward more knowledge about climate developments and contribute to a more enlightened debate about climate changes, Medhaug says.

They both find it very useful to be part of the Bjerknes Centre.

–It is a great advantage. You get to know people who are doing the same as you, says Langehaug.

–And if you have some questions there is always someone working on that field that can help you. All doors are open, and it is easy to get help from peers, Medhaug adds.

PUBLICATIONS IN 2012:

Langehaug, H. R.; Medhaug, I.; Eldevik, T.; Otterå, O. H.: Arctic/Atlantic exchanges via the Subpolar Gyre, Journal of Climate, 2012, Volume 25 (7), doi: 10.1175/JCLI-D-11-00085.1

Langehaug, H. R.; Rhines, P.B.; Eldevik, T.; Mignot, J.; Lohmann, K.: Water mass transformation and the North Atlantic Current in three multicentury climate model simulations, Journal of Geophysical Research – Oceans, 2012, Volume 117, doi: 10.1029/2012JC008021

Langehaug, H. R.; Falck, E.: Changes in the properties and distribution of the intermediate and deep waters in the Fram Strait, Progress in Oceanography, 2012, Volume 96 (1), doi: 10.1016/j.pocean.2011.10.002

Medhaug, I.; Langehaug, H. R.; Eldevik, T.; Furevik, T.; Bentsen, M.: Mechanisms for decadal scale variability in a simulated Atlantic Meridional Overturning Circulation, Climate Dynamics, 2012, Volume 39 (1-2), doi: 10.1007/s00382-011-1124-z

ENGAGEMENTS 2012

IPCC: 5th Assessment report: Prof. Eystein Jansen and Prof. Svein Sundby are Lead Authors in Working Group1 and 2, respectively. Prof. Christoph Heinze and Senior Scientist Ken Drinkwater are Review Editors in Working Groups 1 and 2, respectively. Drs. Trond Dokken, Camille Li and Jerry Tjiputra are contributing authors in Working Group 1.

IPCC: Special report on Extremes: Prof. Asgeir Sorteberg is Lead Author.

RCN Norway-India Programme Advisory Commitee: Prof. Eystein Jansen is a member.

ECRA – European Climate Research Alliance – Prof. Eystein Jansen is member of the executive steering committee.

IS-ENES: Prof. Christoph Heinze is member of the Scientific Advisory Board of the EU FP7 project "Infrastructure for the European Network for Earth System Modelling" (IS-ENES).

ECO2: Prof. Christoph Heinze is member of the Scientific Advisory Board of the EU FP7 project "Sub-seabed CO2 Storage: Impact on Marine Ecosystems" (ECO2)

CARBONES: Prof. Christoph Heinze is member of the Scientific Advisory Board of the EU FP7 project " 30-year re-analysis of CARBON fluxES and pools over Europe and the Globe" (CARBONES)

COST: Senior Scientist Svein Østerhus is a member of the European Cooperation in Science and Technology (COST) action project Everyone's Gliding Observatories Management Committee.
Prof. Christoph Heinze and Caroline Roelandt are members of the management committee of COST action "terrabites".

ESSAC: Ass. Prof. Helga F. Kleiven is Norwegian national alternate in the Ecord Science Support and Advisory Committee (ESSAC).

IMAGES: Prof. Ulysses S. Ninnemann is Norwegian representative in the International Marine Global Changes Program (IMAGES).

ICES Working Group on Hydrography: Senior scientist Svein Østerhus is a member.

International Ocean Carbon Coordination Project (IOCCP). Are Olsen is scientific steering committee member.

OceanSITES: Senior scientist Svein Østerhus is a member of the Steering Committee.

Surface Ocean CO2 Atlas (SOCAT): Dr. Benjamin Pfeil and Dr. Are Olsen are members of the Global Coordination Group.

Arctic Ocean Sciences Board. Harald Loeng, IMR/BCCR is Chair.

European Polar Board. Harald Loeng, IMR/BCCR is a member of Executive Committee.

National Platform for Ocean Research, Hav21, issued by the Norwegian Ministry of Fisheries and coastal affairs: Prof. Helge Drange is a member.

Steering Committee on Climate Change in the Canary Current Large Marine Ecosystem (CCLME): Prof. Svein Sundby is a member of the Steering Committee (under FAO).

European CoOperation in Science and Technology (COST) - Action 735 "Tools for assessing global air-sea CO2 fluxes of climate and air pollutant relevant gasses". Dr. Abdirahman M. Omar was a member of working group 3 in 2006-2011. He has also served as a deputy member in the 735 Action management Committee.

Norwegian Geophysical Society: Is the national society for Norwegian scientists within meteorology, oceanography, hydrology, earth physics, ionosphere physics and vulcanology, and its aim is an improved collaboration within the geophysical sciences. The society is also a connection point to the members' international associations and unions, such as IUGG and EGU. J. Even Ø. Nilsen a member of the board.

Global Climate Forum: BCCR is a member of the Global Climate Forum (GCF), a non-profit organization located at PIK in Potsdam, Germany. GCF is a platform for joint studies and science-based stakeholder dialogues on climatic change and brings together representatives of different parties concerned with the climate problems.

Bergen Climate Forum: The climate forum is a local meeting point for people from the industry and commerce, authorities, organizations, and educational- and research institutions. It is collaboration between the Bjerknes Centre, the Bergen Chamber of Commerce and Industry and the Municipality of Bergen.

International Geosphere-Biosphere programme (IGBP) and World Climate Research Program (WCRP):

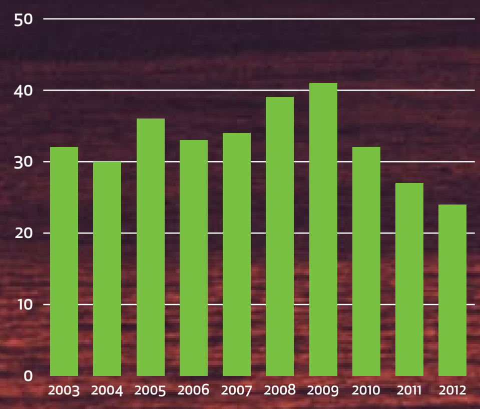
- Integrated Project CARBOCHANGE, coordinated by Prof. Christoph Heinze, was endorsed by the IGBP/SCOR sponsored projects SOLAS and IMBER.
- Surface Ocean Lower Atmosphere Study (SOLAS). Prof. Christoph Heinze is a member of the SSC. Dr. Abdirahman M. Omar is the Norwegian National Representative.
- International Ocean Carbon Coordination Project (IOCCP). Prof. Truls Johannessen is an ex-officio science steering committee member.
- Integrated Marine Biogeochemistry and Ecosystem Research (IMBER). Ken Drinkwater is an SSC member.
- Ecosystem Studies of Subarctic Seas (ESSAS). Ken Drinkwater is co-chair of this IMBER regional program.
- PAGES (Past Global Changes). Ulysses Ninnemann is on the SSC of IMAGES, the marine component of PAGES.
- PAGES Arctic 2k working group. Martin Miles is a member.
- PAGES/CLIVAR joint working group. Eystein Jansen is a member.
- Climate Variability and Predictability (CLIVAR). Ken Drinkwater is a member of the Scientific Steering Group (SSG).
- Prof. Helge Drange is co-leader of the CLIVAR Working Group for Ocean Model Development (WGOCMD)
- Scientific Advisory Boards. Eystein Jansen is member of the scientific advisory board of IC3-Climate Centre, Barcelona.
- Helge Drange is on the advisory board of MARUM, University of Bremen

10 YEARS AS CENTRE OF EXCELLENCE **IN PERSPECTIVE**

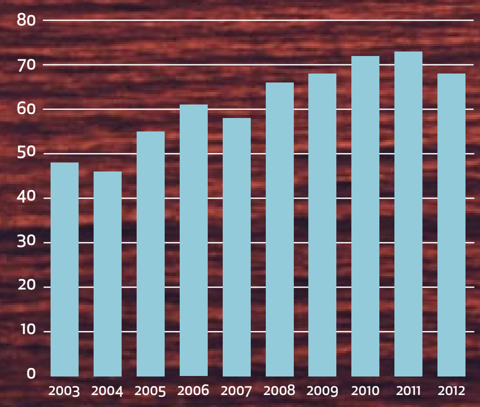
The CoE activities of the Bjerknes Centre were characterised by a strong growth in scientific personell, in research output and scientific activity. The centre has produced more than 1100 peer review scientific papers, 63 PhD degrees have been awarded within the CoE. Total funding of the centre amounts to 817 mill NOK, of which 330 mill NOK are from research grants from the Rsearch Council, from EU and various public and private sources. The core funding of the CoE amounts to 170 mill NOK, and in kind contributions from the partners (primarily the University of Bergen) amounts to 317 mill NOK.

As can be seen in the graphs to the right there has been a steady rise in peer review publications. The rise is higher than the increase in per-sonell, indicating higher scientific productivity with time. Bibliometric analyses have documented high impact of BCCR research, showing that Bjerknes centre papers are cited twice as often as the global and national mean
in the same disciplines. 38 papers are published in Nature (including daughter journals) and Science. The income from external grants has been more variable, and reached a maximum in 2009. The decline since then is primarily caused by a reduction in funding availability from the Research Council with less money available for climate system research.

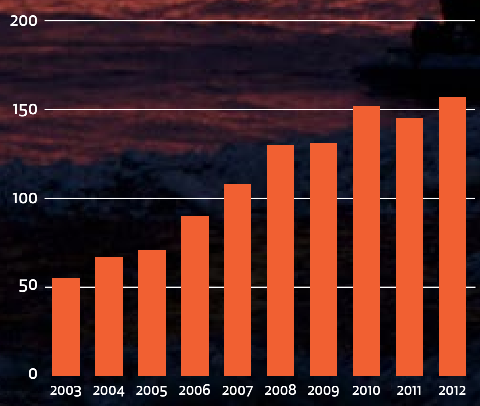
EXTERNAL PROJECTS

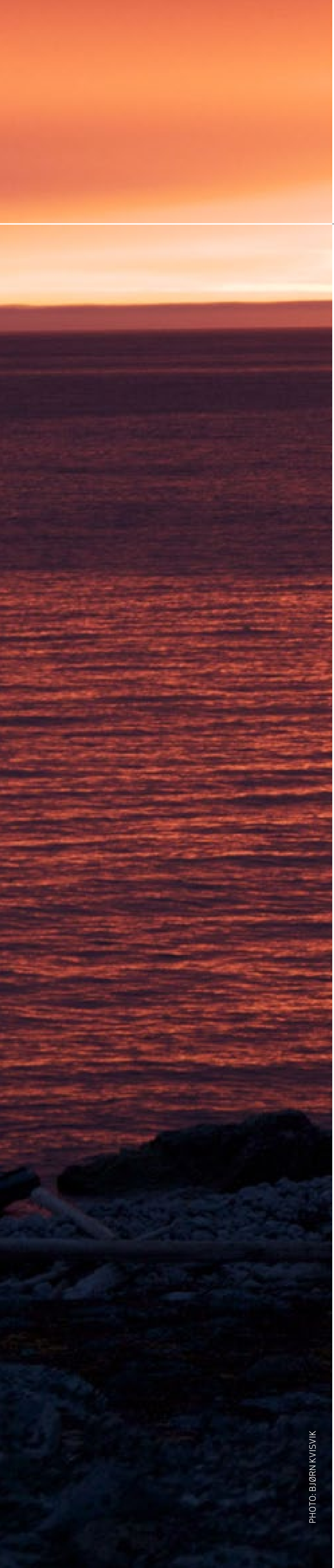


NUMBER OF SCIENTISTS



PEER REVIEW PAPERS





ORGANISATION AND FINANCES 2012

THE DIRECTOR AND THE LEADER FORUM

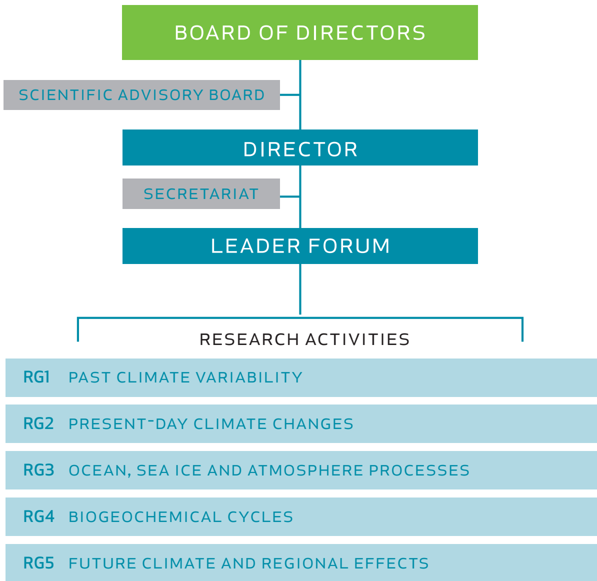
The Director and the Research Group Leaders are key members of the Leader Forum, which deals with scientific and professional issues.

Eystein Jansen	Professor (Director) Paleoclimatology, Uni Research/UiB
Kerim Nisancioglu	Scientist, Paleoclimatology, Uni Research
Helga F. Kleiven	Scientist, Paleoclimatology, UiB/Uni Research
Tor Eldevik	Scientist, Ocean processes and modelling, UiB
Christoph Heinze	Professor Carbon cycle modelling, UiB/Uni Research
Frode Vikebø	Scientist, Oceanography, IMR
Birgit Falch	Cand.Polit, Science coordinator, Uni Research
Gudrun Sylte	Head of Communication, Uni Research

RESEARCH GROUPS

The Research Groups are focused teams including scientists, students and technical staff that combine observations with numerical modelling.

		LEADER (CO-LEADER)
RG1	Past Climate Variability	K. Nisancioglu (A. Nesje)
RG2	Present-Day Climate Changes	H. F. Kleiven (A.B. Sandø)
RG3	Ocean, Sea ice and Atmosphere Processes	T. Eldevik (I. Fer / I. Esau)
RG4	Biogeochemical Cycles	C. Heinze (R. Bellerby)
RG5	Future Climate and Regional Effects	F. Vikebø (M. d. S. Mesquita)



THE BOARDS

BOARD OF DIRECTORS

Tore Nepstad	Director, Institute of Marine Research (Chair)
Peter M. Haugan/Stein Sandven	Director, Nansen Environmental and Remote Sensing Center
Dag Rune Olsen	Dean, Faculty of Mathematics and Natural Sciences, UiB
Arne Svindland	Director, Uni Research

SCIENTIFIC ADVISORY BOARD

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Lennart Bengtsson	Max Plank Institute for Meteorology, Germany
Raymond Bradley	Climate System Research Center, University of Massachusetts, USA
Øystein Hov	Norwegian Meteorological Institute, Norway
Jerry McManus	Woods Hole Oceanographic Institution, USA
Peter Rhines	Dept. of Oceanography, University of Washington, Seattle, USA
Rowan Sutton	Centre of Global Atmospheric Modelling, University of Reading, UK
John Walsh	International Arctic Research Centre, University of Alaska, Fairbanks, USA
Andrew Watson	School of Environmental Sciences, University of East Anglia, UK

View over Bergen.
PHOTO: WILLEM VAN DER BILT

FUNDING AND EXPENSES

Project financing constitutes the main funding resource for the Bjerknes Centre for Climate Research (BCCR). The CoE (Centre of Excellence) funding and other projects from the Research Council of Norway are a substantial source of financing for the BCCR. There are several ongoing programmes in which the Bjerknes Centre is involved. There are 16 projects funded by the Research Council of Norway, with BCCR scientists leading 14 of these projects. Eleven ongoing projects are funded by the 7th Framework Program of

the European Commission, of which BCCR coordinates two of the projects. See Appendix 2 for a complete listing of ongoing research projects. The second main funding source is the contribution to the CoE activities from the partner institutions, including the University of Bergen, the Nansen Environmental and Remote Sensing Center and the Institute of Marine Research.

FUNDING	(1000 NOK)
The Research Council of Norway, CoE	17 000
The Research Council of Norway, other projects	8 312
University of Bergen	24 609
Nansen Environmental and Remote Sensing Center	10
Institute of Marine Research	2 144
EU projects	7 944
Other private funds	4 163
Other public funds	3 459
Total funding	**67 641**

EXPENSES	(1000 NOK)
Salaries and building rental costs	49 077
Research equipment	870
External research services	4 214
Other costs	7 480
Total expenses	**61 641**

STAFF 2012

SCIENTISTS

Jürgen	Bader	Germany	Uni Research	Climate modelling
Jostein	Bakke		UiB	Palaeoclimatology
David	Battisti	USA	UiB	Atmospheric dynamics, paleo-modelling
Richard	Bellerby	UK	Uni Research	Biogeochemistry
Mats	Bentsen		Uni Research	Climate modelling
Ingo	Bethke	Germany	Uni Research	Ocean modelling
Bhuvan	Bhatt	Nepal	Uni Research	Meteorology
Hilary	Birks	UK	UiB	Numerical methods in palaeoclimatology
H. John B.	Birks	UK	UiB	Terrestrial biological climate proxies
Anne Elisabeth	Bjune		Uni Research	Palaeobotany
Paul	Budgell	Canada	IMR	Ocean modelling development
Carin Andersson	Dahl	Sweden	Uni Research	Palaeoclimatology
Svein Olaf	Dahl		UiB	Glaciers & palaeoclimatology
Trond Martin	Dokken		Uni Research	Palaeoclimatology
Helge	Drange		UiB	Climate modelling
Ken	Drinkwater	Canada	IMR	Oceanography & impacts of climate change
Tor	Eldevik		UiB	Ocean processes & modelling
Igor	Esau	Russia	NERSC	Environmental boundary layers
Ilker	Fer	Turkey	UiB	Ocean processes
Helene	Frigstad		Uni Research	Impacts of ocean acidification
Tore	Furevik		UiB	Climate dynamics
Tor	Gammelsrød		UiB	Polar oceanography
Yongqi	Gao	China	NERSC	Ocean circulation modelling
Christoph	Heinze	Germany	UiB	Carbon cycle modelling
Solfrid	Hjøllo		IMR	Ocean circulation
Mehmet	Ilicak	Turkey	Uni Research	Oceanography
Randi	Ingvaldsen		IMR	Physical oceanography
Nil	Irvali	Turkey	Uni Research	Palaeoclimatology
Emil	Jeansson	Sweden	Uni Research	Chemical oceanography
Eystein	Jansen		Uni Research	Palaeoclimatology
Truls	Johannessen		UiB	Biogeochemistry
Noel	Keenlyside	Australia	UiB	Tropical meteorology
Helga Flesche	Kleiven		UiB	Palaeoclimatology
Helene	Langehaug		Nersc	Ocean dynamics, climate modelling
Camille	Li	Canada	UiB/Uni Research	Atmospheric dynamics and paleoclimate
Øyvind	Lie		Uni Research	Palaeoclimatology
Torleif M.	Lunde		Uni Research	Climate modelling
Kjetil	Lygre		NERSC	Biogeochemistry & modelling
Jan	Mangerud		Uni Research	Palaeoclimatology
Michel	dos Santos Mesquita	Brazil	Uni Research	Atmospheric dynamics
Martin	Miles	USA	Uni Research	Climate time series analysis
Atle	Nesje		UiB	Palaeoclimatology
Jan Even Øie	Nilsen		NERSC	Physical oceanography

Ulysses S.	Ninnemann	USA	UiB	Palaeoclimatology
Kerim Hestnes	Nisancioglu		Uni Research	Palaeoclimatology & modelling
Are Christian S.	Olsen		UiB	Chemical oceanography
Abdirahman	Omar	Somalia	Uni Researc	Chemical oceanography
Odd Helge	Otterå		Uni Research	Climate modelling
Emanuele	Reggiani	Italy	Uni Research	Chemical oceanography
Kristin	Richter	Germany	UiB	Ocean dynamics
Bjørg	Risebrobakken		Uni Research	Palaeoclimatology
Anne Britt	Sandø		IMR	Ocean modelling
Corinna	Schrum	Germany	UiB	Ocean modelling
Øystein	Skagseth		IMR	Ocean circulation
Ingunn	Skjelvan		Uni Research	Chemical oceanography
Lars Henrik	Smedsrud		Uni Research	Polar Oceanography
Stefan	Sobolowski	USA	Uni Research	Atmospheric modelling and dynamics
Asgeir	Sorteberg		UiB	Climate modelling
Thomas	Spengler	Germany	UiB	Dynamic Meteorology
Svein	Sundby		IMR	Ocean climates
John Inge	Svendsen		UiB	Palaeoclimatology
Henrik	Søiland		IMR	Ocean modelling
Jerry	Tjiputra	Indonesia	Uni Research	Carbon cycle modelling
Frode	Vikebø		IMR	Climate impacts on marine ecosystems
Zhongshi	Zhang	China	Uni Research	Paleoclimatology and modelling
Svein	Østerhus		Uni Research	Physical oceanography
Bjørn	Ådlandsvik		IMR	Physical oceanography and modelling

POSTDOCS

Roohollah	Azad	Iran	UIB	Regional atmospheric modelling
Jon	Bergh	Sweden	Nersc	Meteorology, oceanography
Elin Darelius	Chiche	Sweden	UiB	Polar oceanography
Mirjam	Glessmer	Germany	UIB	Climate dynamics
Nadine	Goris	Germany	UiB	Chemical Oceanography
Siv Kari	Lauvset		UiB	Chemical oceanography
Caroline	Roelandt	Belgium	UiB	Terrestrial Biogeochemical modelling
Jörg	Schwinger	Germany	UiB	Carbon cycle modelling
Anders	Sirevaag		UiB	Physical Oceanography
Lingling	Suo	China	NERSC	Climate dynamics
Jerry	Tjiputra	Indonesia	UiB	Carbon cycle modelling
Kjetil	Våge		UiB	Physical Oceanography
Yu	Lei	China	UIB	Atmospheric modelling and dynamics

PhD STUDENTS

Vivian Astrup	Felde		Uni Research	Terrestrial plant biodiversity
Eirik	Galaasen		UiB	Palaeoclimatology
Vidar	Lien		IMR	Regional ocean modelling
Tor L.	Mjell		UiB	Paleoclimatology
Anna	Silyakova	Russia	Uni Research	Biogeochemistry
Andrea	Tegzes	Hungary	Uni Research	Palaeoclimatology
Amandine	Tisserand	France	UiB/Uni Research	Palaeoclimatology
Kristian	Vasskog		UiB	Extreme weather events in the past
Marius	Årthun		UiB	Ocean modelling

TECHNICAL STAFF

Lukas	Becker	Germany	Uni Research	Palaeoclimatology
Dagfinn	Bøe		Uni Research	Palaeoclimatology
Tor	de Lange		UiB	Chemical Oceanography
Odd Reidar	Hansen		UiB	Palaeoclimatology
Ingeborg	Helvik		Uni Research	Paleobotany
Espen	Karlsen		Uni Research	Meteorology, oceanography
Solveig	Kringstad		UiB	Chemical Oceanography
Bjørn Christian	Kvisvik		Uni Research	Palaeoclimatology
Lea Toska	Oppedal		Uni Research	Palaeoclimatology
Benjamin	Pfeil	Germany	Uni Research	Data manager
Rune Egil	Søraas		Uni Research	Palaeoclimatology
Jørund	Strømsøe		Uni Research	Palaeoclimatology
Aslaug Skålevik	Valved		Uni Research	Meteorology, oceanography

ADMINISTRATION

Lars	Fagerli		Uni Research	Financial officer
Birgit	Falch		Uni Research	Research coordinator
Kim Andreas	Herøy		Uni Research	Senior Secretary
Beate	Klementsen		Uni Research	HR Manager
Charla Melander	Olsen	USA	Uni Research	Administrative consultant
Gudrun Urd	Sylte		Uni Research	Head of communication
Andrea	Volbers	Germany	Uni Research	Researcher


PHOTO: ANNE BJUNE

PERSONELL SUMMARY

Category	Person-years
Scientists	28,5
Postdocs	7,7
PhD students	5,9
Technicians	8,0
Administration	5,3
Total	**55,4**

STAFF BY PARTNER INSTITUTION

Number of scientific personell, sorted by category and partners.

Category	Uni Research	UiB	IMR	NERSC	Total	Non-Norwegian (%)	Female (%)
Scientists	30	23	10	5	68	46	24
Postdocs	0	11	0	2	13	77	46
PhD students	4	5	1		10	40	50
Total					**91**		

STAFF BY NATIONALITY

The Bjerknes Centre recruits personell internationally. In 2012, 19 nationalities were represented at the BCCR.

Country	#personell
Australia	1
Brazil	1
Belgium	1
Canada	3
China	4
France	1
Germany	12
Hungary	1
Indonesia	1
Iran	1
Italy	1
Nepal	1
Norway	62
Russia	2
Somalia	1
Sweden	4
Turkey	3
UK	3
USA	5
Total	**108**

RESEARCH PROJECTS

Projects funded by the Research Council of Norway

Title	Duration	*Leader/ **Partner
East Asian DecCen: Exploring decadal to century scale variability and changes in the East Asian climate during the last millennium (DecCen)	2009–12	T. Furevik*
Ecosystem change in the North Sea: Processes, drivers, future scenarios (ECODRIVE)	2009–12	M. Skogen**
Atlantic Meridional Overturning Circulation during Interglacials (AMOCINT)	2007–12	E. Jansen*
Norwegian component of the Ecosystem Studies of Subarctic and Arctic Regions (NESSAR)	2007–12	K. Drinkwater*
Storfjorden Polynya Air Sea Ice Exchange Experiment (SPASIE)	2010–12	L. H. Smedsrud*
A user-defined approach to utilize climate change information in local implementation of national construction standards (RECON)	2010–13	I. Ezau*
Biotic response to climate change in cold climates (BIOCOLD)	2010–13	A. Bjune*
An Integrated Earth System Approach to Explore Natural Variability and Climate Sensitivity (EARTHCLIM)	2011–13	H. Drange*
Impact of Blue Arctic on Climate at High Latitudes (BLUEARC)	2011–13	Y. Gao*
North-Atlantic Ocean- Climate Variability in a Warmer World (NOCWARM)	2011–13	H. F. Kleiven*
Terrestrial biodiversity through time - novel methods and their applications (LAND)	2011–13	A. Bjune*
Southern Ocean Variability – Contemporary to Paleo Trends (SO-VAR)	2011–14	U. Ninnemann*
Antarctic Ice Shelves and Ocean Climate: Produciton, Export, Dynamics and Variability of Bottom Water in the Southern Weddell Sea	2011–13	I. Fer*
Climate Change and its Impacts on Selected Indian Hydrological Systems using Earth System and High-Resolution Modelling (NORINDIA)	2012–15	M. Mesquita *
Norwegian Marine Data Centre (NMDC)	2012–22	S. Østerhus **
Developing a method to measure UV-B flux through time using aromatic compounds contained in fossil pollen and leaf cuticle (UV-B flux)	2012–15	A. Bjune**

Projects funded by the 7th Framework Program of the European Commission

Title	Duration	Type	Leader/Scientist
Thermohaline Overturning – at Risk? (THOR)	2008–11	IP ◆	H. F. Kleiven T. Eldevik
The European Project on Ocean Acidification (EPOCA)	2008–12	IP ◆	C. Heinze
Marine Ecosystem Evolution in a Changing Environment (MEECE)	2008–13	IP ◆	R. Bellerby
Integration and enhancement of key existing European deep-ocean observatories (EUROSITES)	2008–12	IP ◆	S. Østerhus
Climate Change – Learning from the past climate (Past4Future)	2010–14	IP ◆	T. Dokken
Development of global plankton data base and model system for eco-climate early warning (GREENSEAS)	2010–13	IP ■	J. Johannessen
Basin-scale Analysis, Synthesis and Integration (EUROBASIN)	2010–14	IP ◆	R. Bellerby
Enabling Climate Information Services for Europe (ECLISE)	2011–14	IP ◆	N. G. Kvamstø
Changes in Carbon uptake and emissions by oceans in a changing climate (CARBOCHANGE)	2011–15	IP ■	C. Heinze
Quantifying projected impacts under 2°C warming (IMPACT2C)	2011–15	IP ◆	M. Mesquita dos Santos
North Atlantic Climate: Predictability of the climate in the North Atlantic/European sector related to North Atlantic/Arctic sea surface temperature and sea ice variability and change (NACLIM)	2012-15	*IP* ◆	S. Østerhus

BCCR is ■ Coordinator or ◆ Partner

Projects funded by other sources

Title	Duration	Leader/Scientist	Funding source
WestPrecip – Scenarios for future precipitation in the Western Norway, a sub project under MARE	2009–12	H. Drange	Bergen municipality
Changes in past, present and future sea level, with focus on Western Norway, linked to MARE	2009–12	J. E. Ø. Nilsen	Bergen municipality
Fimbul ice shelf – Top to bottom	2009–12	L. H. Smedsrud	Norwegian Polar Institute
Earth System Modelling (ESM)	2009–14	K.H. Nisancioglu	Statoil ASA
University of Washington – University of Bergen Climate Change Network	2006–12	T. Furevik	SIU
Paleoclimate in the Southern Ocean	2004–13	U. Ninnemann	Comer Foundation
Arealplanlegging og beredskap for fremtidens klima (AREALKLIM)	2012–14	M. Miles	Regionale Forskningsfond Vestlandet

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SELECTED PUBLICATIONS

Bjerknes researchers published 120 articles in international peer reviewed journals in 2012.
For a complete listing, please visit www.bjerknes.uib.no/publications. Bjerknes scientists are indicated in **bold**.

1. Alexeev, V.A.; **Esau, Igor;** Polyakov, Igor V; Byam, S.J; **Sorokina, Svetlana.**
Vertical structure of recent arctic warming from observed data and reanalysis products. Climatic Change 2012 ; Volume 111.(2) pp. 215–239
2. **Bader, Jürgen;** Flügge, Martin; **Kvamstø, Nils G; Mesquita, Michel D Santos; Voigt, Andre**.
Atmospheric winter response to a projected future Antarctic sea-ice reduction: a dynamical analysis. Climate Dynamics 2012
3. **Barstad, Idar; Sorteberg, Asgeir; Mesquita, Michel D Santos.**
Present and future offshore wind power potential in northern Europe based on downscaled global climate runs with adjusted SST and sea ice cover. Renewable Energy 2012 ; Volume 44. pp. 398–405
4. **Bentsen, Mats; Bethke, Ingo;** Debernard, JB; Iversen, T; Kirkevåg, A; Seland, Øyvind; **Drange, Helge; Roelandt, Caroline;** Seierstad, Ivar A.; Hoose, Corinna; Kristjansson, Jon Egill.
The Norwegian Earth System Model, NorESM1-M. Part 1: Description and basic evaluation.
Geoscientific Model Development Discussions 2012 ; Volume 5. pp. 2843–2931
5. **Bethke, Ingo; Li, Camille; Nisancioglu, Kerim Hestnes.**
Can we use ice sheet reconstructions to constrain meltwater for deglacial simulations?. Paleoceanography 2012 ; Volume 27.
6. **Birks, Hilary H; Jones,** Vivienne J.; Brooks, Stephen J.; **Birks, Harry John Betteley;** Telford, Richard; Juggins, Steve; Peglar, Sylvia Margaret.
From cold to cool in northernmost Norway: Lateglacial and early Holocene multi-proxy environmental and climate reconstructions from Jansvatnet, Hammerfest. Quaternary Science Reviews 2012 ; Volume 33. pp. 100–120
7. **Born, Andreas;** Mignot, Juliette.
Dynamics of decadal variability in the Atlantic subpolar gyre: a stochastically forced oscillator.
Climate Dynamics 2012 ; Volume 39.(1–2) pp. 461–474
8. **Born, Andreas; Nisancioglu, Kerim Hestnes.**
Melting of Northern Greenland during the last interglaciation. The Cryosphere 2012 ; Volume 6.(6) pp. 1239–1250
9. De Deckker, Patrick; Moros, Matthias; Perner, Kerstin; **Jansen, Eystein.**
Influence of the tropics and southern westerlies on glacial interhemispheric asymmetry. Nature Geoscience 2012 ; Volume 5.(4) pp. 266–269
10. **Esau, Igor; Davy,** Richard; Outten, Stephen.
Complementary explanation of temperature response in the lower atmosphere. Environmental Research Letters 2012 ; Volume 7.(4)
11. **Heikkila, Ulla Elina; Sorteberg, Asgeir.**
Characteristics of autumn-winter extreme precipitation on the Norwegian west coast identified by cluster analysis.
Climate Dynamics 2012 ; Volume 39. (3–4) pp. 929–939
12. **Irvali, Nil; Ninnemann, Ulysses S; Galaasen, Eirik Vinje;** Rosenthal, Yair; Kroon, Dick; Oppo, Delia W.; **Kleiven, Helga Flesche;** Darling, Kate F.; Kissel, Catherine.
Rapid switches in subpolar North Atlantic hydrography and climate during the Last Interglacial (MIS 5e). Paleoceanography 2012 ; Volume 27.
13. Iversen, Trond; **Bentsen, Mats; Bethke, Ingo;** Debernard, JB; Kirkevåg, Alf; Seland, Øyvind; **Drange, Helge;** Kristjansson, Jon Egill; **Medhaug, Iselin;** Sand, Maria; Seierstad, Ivar A.
The Norwegian Earth System Model, NorESM1-M – Part 2:Climate response and scenario projections.
Geoscientific Model Development 2012 ; Volume 5.(3) pp. 2933–2998
14. Jiang, Jonathan H.; Su, Hui; Zhai, Cheng Xiang; Perun, Vincent S.; Del Genio, Anthony; Nazarenko, Larissa S.; Donner, Leo J.; Horowitz, Larry W; Seman, Charles; Cole, Jason; Gettelman, Andrew; Ringer, Mark A.; Rotstayn, Leon; Jeffrey, Stephen; Wu, Tongwen; Brient, Florent; Dufresne, Jean-Louis; Kawai, Hideaki; Koshiro, Tsuyoshi; Watanabe, Masahiro; LEcuyer, Tristan S.; Volodin, Evgeny M.; Iversen, Trond; **Drange, Helge; Mesquita, Michel D Santos;** Read, William G.; Waters, Joe W.; Tian, Baijun; Teixeira, João Paulo; Stephens, Graeme L..
Evaluation of cloud and water vapor simulations in CMIP5 climate models using NASA "A-Train" satellite observations.
Journal of Geophysical Research - Atmospheres 2012 ; Volume 117.
15. Kabel, Karoline; Moros, Matthias; Porsche, C.; Neumann, Thomas; Adolphi, Florian; Andersen, Thorbjørn J.; Siegel, Herbert; Gerth, Monika; Leipe, Thomas; **Jansen, Eystein;** Damsté, Jaap Sinninghe.
Impact of climate change on the Baltic Sea ecosystem over the past 1,000 years. Nature Climate Change 2012; Volume 2, pp. 871–874
16. Keller, Kathrin; Joos, Fortunat; Raible, Christoph C.; Cocco, Valentina; Froelicher, Thomas; Dunne, John; Gehlen, Marion; Bopp, Laurent; Orr, James C.; **Tjiputra, Jerry; Heinze, Christoph;** Segschneider, Joachim; Roy, Tilla; Metzl, Nicolas.
Variability of the ocean carbon cycle in response to the North Atlantic Oscillation. Tellus B 2012 ; Volume 64. pp. 1–25
17. **Kvamstø, Nils Gunnar;** Steinskog, Dag Johan; Stephenson,, David; Tjøstheim, Dag Bjarne.
Estimation of trends in extreme melt-season duration at Svalbard. International Journal of Climatology 2012 ; Volume 32.(14) pp. 2227–2239

18. **Langehaug, Helene R.; Medhaug, Iselin; Eldevik, Tor; Otterå, Odd Helge.**
Arctic/Atlantic exchanges via the Subpolar Gyre. Journal of Climate 2012 ; Volume 25. (7) pp. 2421–2439

19. **Langehaug, Helene R.;** Rhines, P.B.; **Eldevik, Tor;** Mignot, J.; Lohmann, K.
Water mass transformation and the North Atlantic Current in three multicentury climate model simulations.
Journal of Geophysical Research – Oceans 2012; Volume 117.

20. **Li, Camille; Wettstein, Justin.**
Thermally-driven and eddy-driven jet variability in reanalysis. Journal of Climate 2012 ; Volume 25.(5) pp. 1587–1596

21. **Medhaug, Iselin; Langehaug, Helene Reinertsen; Eldevik, Tor; Furevik, Tore; Bentsen, Mats.**
Mechanisms for decadal scale variability in a simulated Atlantic Meridional Overturning Circulation.
Climate Dynamics 2012 ; Volume 39. (1–2) pp. 77–93

22. **Richter, Kristin; Nilsen, Jan Even Øie; Drange, Helge.**
Contributions to sea level variability along the Norwegian coast for 1960-2010. Journal of Geophysical Research - Oceans 2012 ; Volume 117.

23. **Richter, Kristin; Segtnan, Ole Henrik Andengaard; Furevik, Tore.**
Variability of the Atlantic inflow to the Nordic Seas and its causes inferred from observations of sea surface height.
Journal of Geophysical Research - Oceans 2012 ; Volume 117.

24. **Sandø, Anne Britt; Nilsen, Jan Even Øie; Eldevik, Tor; Bentsen, Mats.**
Mechanisms for variable North Atlantic-Nordic seas exchanges. Journal of Geophysical Research - Oceans 2012 ; Volume 117.(C12)

25. Signorini, Sergio R.; Häkkinen, Sirpa; Gudmundsson, Kristinn; **Olsen, Are; Omar, Abdirahman;** Ólafsson, Jón; Reverdin, Gilles; Henson, Stephanie A.; McClain, Charles R.; Worthen, Denise L.
The role of phytoplankton dynamics in the seasonal and interannual variability of carbon in the subpolar North Atlantic – a modeling study.
Geoscientific Model Development 2012 ; Volume 5.(3) pp. 683–707

26. **Sirevaag, Anders; Fer, Ilker.**
Vertical heat transfer in the Arctic Ocean: the role of double-diffusive mixing. Journal of Geophysical Research - Oceans 2012 ; Volume 117

27. **Skagseth, Øystein; Mork, Kjell Arne.**
Heat content in the Norwegian Sea, 1995–2010. ICES Journal of Marine Science 2012 ; Volume 69.(5) pp. 826–832

Rødsildre, Svalbard. PHOTO: ANNE BJUNE

28. **Støren, Eivind Wilhelm Nagel;** Kolstad, Erik Wilhelm; Paasche, Øyvind.
Linking past flood frequencies in Norway to regional atmospheric circulation anomalies.
Journal of Quaternary Science 2012 ; Volume 27.(1) pp. 71–80

29. **Telford, Richard; Li, Camille;** Kucera, M.
Mismatch between the depth habitat of planktonic foraminifera and the calibration depth of SST transfer functions may bias reconstructions.
Climate of the Past Discussions 2012 ; Volume 8. pp. 4075–4103

30. **Tjiputra, Jerry; Olsen, Are;** Assmann, Karen Margarete; **Pfeil, Benjamin; Heinze, Christoph.**
A model study of the seasonal and long-term North Atlantic surface pCO(2) variability. Biogeosciences 2012 ; Volume 9.(3) pp. 907–923

31. Tzedakis, P. Chronis; Channell, James E.T.; Hodell, David A.; **Kleiven, Helga Flesche;** Skinner, Luke C..
Determining the natural length of the current interglacial. Nature Geoscience 2012 ; Volume 5.(2) pp. 138–141

32. **Vasskog, Kristian;** Paasche, Øyvind; **Nesje, Atle;** Boyle, John F.; **Birks, Harry John Betteley.**
A new approach for reconstructing glacier variability based on lake sediments recording input from more than one glacier.
Quaternary Research 2012 ; Volume 77.(1) pp. 192–204

33. **Viste, Ellen; Sorteberg, Asgeir.**
The effect of moisture transport variability on Ethiopian summer precipitation. International Journal of Climatology 2012

34. Wang, Tao; **Otterå, Odd Helge; Gao, Yongqi;** Wang, Huijun.
The response of the North Pacific Decadal Variability to strong tropical volcanic eruptions. Climate Dynamics 2012 ; Volume 39.(12) pp. 2917–2936

35. **Zhang, Zhongshi; Nisancioglu, Kerim Hestnes; Bentsen, Mats; Tjiputra, Jerry; Bethke, Ingo; Yan, Qing; Risebrobakken, Bjørg; Andersson, Carin; Jansen, Eystein.**
Pre-industrial and mid-Pliocene simulations with NorESM-L. Geoscientific Model Development 2012 ; Volume 5.(2) pp. 523–533

36. **Årthun, Marius; Bellerby, Richard; Omar, Abdirahman; Schrum, Corinna.**
Spatiotemporal variability of air-sea CO2 fluxes in the Barents Sea, as determined from empirical relationships and modeled hydrography.
Journal of Marine Systems 2012 ; Volume 98–99. pp. 40–50

37. **Årthun, Marius; Eldevik, Tor; Smedsrud, Lars Henrik; Skagseth, Øystein; Ingvaldsen, Randi.**
Quantifying the influence of Atlantic heat on Barents Sea ice variability and retreat. Journal of Climate 2012 ; Volume 25.(13)pp. 4736–4743

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